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AVIATION MEDICINE

A. A. Lavnikov

Translation of "Aviatsionnaya meditsina."
Voyenizdat, Moscow, 1961.

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By A. A. Lavnikov

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TABLE OF CONTENTS

Page

TRANSLATOR'S NOTES

The subject range of the book is extremely wide and largely elementary. In its direct information content, the book has little to offer that is not common knowledge or often considered today to be obsolete. However, A. A. Lavnikov's "Aviatsionnaya Meditsina" has some value to the reader who is predominantly interested in evaluating Soviet Air Force personnel training and the presentation of popular ideas concerning passive defense against nuclear attack. Certain passages, i.e., those devoted to personal hygiene, may also give some insight into the type of personnel being recruited into the Soviet Armed Forces. Being solely a teaching manual addressed to flying and ground personnel, it indicates clearly the respective levels of such an audience. By Western standards, the method of presentation and the teaching often appear very outdated. In order to stress a point which may not be clear, the author simply repeats the argument in unchanged form.

Certain presentations of fundamental and quite simple principles, such as Newton's laws of motion or the "two-bodies" problems connected with pilot-ejection considerations, are explained in a particularly clumsy fashion. This is surprising since there are a number of excellent popular science books in the Soviet Union giving a crisp and non-ambiguous presentation. The earlier chapters describing anatomy and physiology of man seem better than the later ones.

It is interesting to note that although it is known to us that some work has been carried out behind the Iron Curtain on combating high-altitude anoxia by means of drugs, no mention to this effect is made in the book. Of equal interest is the presentation of the defense against nuclear attack and particularly against exposure to ionizing radiations. Here again, the mechanisms of the so-called "direct theory" (i.e., in which it is assumed that the impinging quantum of ionizing radiation attacks directly the "genetic matter") and the "indirect theory" (according to which the impinging radiation ionizes the water molecules and the resulting free radicals do the actual damage by reacting with the genetic matter) are presented in a rather misleading way. Furthermore, although we know here that people such as Dr. G. A. Zedgenidze and others at the Institute of Medical Radiology in Moscow were very advanced in evaluating possible use of drugs securing protective action against ionizing radiations, working on the principle of the indirect theory of radiation damage, no mention of this means of protection is to be found in the book. Certain other data, particularly those concerning the toxicity of substances encountered in aviation, also require rectification. According to data of H. Specht - "Toxicology of Travel in Aeropause" ("Physics of

Medicine of the Upper Atmosphere", Ed. Clayton S. White, University of New Mexico Press, 1952) the maximum concentration of toxic substances for chronic exposures is as follows: (in p.p.m.) ozone - 1.0; nitrous and nitric acid - 10-40; nitrogen dioxide - 25; acrolein - 1.0; carbon monoxide - 100. The toxicity of ozone is frequently being reviewed and the present figure is even lower than 0.5 p.p.m.

Certain statements made by Lavnikov relating to Western work seem to be simply the result of either poor translation or misinterpretation of the data. This applies particularly to a passage concerned with the survival of animals exposed to the effects of acute dysbarism. Lavnikov quotes some of the American sources as erroneous. It appears that he was not sufficiently familiar with the contents of the paper "The General Tolerance and Cardio-Vascular Responses of Animals to Explosive Decompression" (by W. V. Whitehorn, A. Lein and A. Edelmann: American Journal of Physiology, vol. 147, pp. 289-298, 1946), which clarifies the points raised. Some of the data concerned with engineering aspects (Human Engineering) are particularly obsolete. The author may not have had at his disposal some of the literature on the subject published in the U.S.A. (for instance, "Human Engineering" by Ernest J. McCormick, McGraw-Hill, 1957) but there are other books that have been published in the Soviet Union, the contents of which could have contributed to bringing "Aviatsionnaya Meditsina" more up-to-date.

It is particularly surprising that the references do not mention the Soviet book "High Altitude Aircraft Equipment" by Bykov, Yegorov and Tarasov (which has been translated into English).

The very poor quality of the book is puzzling since it appears from the references given that the author is not a novice; a textbook "Aviation Medicine" by him was published in 1957 and, in addition, the bibliography lists five papers by him on fields covered in this book, which were published between 1949-1959. The fact that the chapters on anatomy and physiology are slightly better written than the rest seems to indicate that the author is a medical man who drifted into aviation medicine but failed to absorb the minimum knowledge of physics required for understanding the subject matter dealt with in this book.

PREFACE

During the last few years aircraft fitted with jet engines have made it possible to fly at speeds considerably exceeding the speed of sound, and also to fly at very high altitudes. Flights at such speeds and altitudes, and particularly under difficult meteorological conditions or in combat, impose on man great psychological and physical stresses.

The development of aviation is closely linked with aviation medicine.

The task of aviation medicine should be the creation of more favorable and scientifically justified hygienic conditions for the flight personnel during flight, while also ensuring reliable physiologically substantiated means of rescue during emergency situations arising in the air.

In ensuring favorable conditions which increase the safety of flights, the knowledge of the influence of the various flight factors on the human body plays an important role. For that reason the entire flight staff should acquaint themselves with the basic problems of aviational physiology and hygiene.

AVIATION MEDICINE

A. A. Lavnikov

This textbook deals with some problems of anatomy and physiology relevant to the presentation of the subsequent chapters, namely, high altitude flight physiology, basic hygienic requirements of aircraft cabins, principles of physiological-hygiene, physiological-hygiene principles of oxygen-breathing apparatus, acceleration during aircraft flight and its influence on the body of the pilot, aspects of physiological-health principles of emergency rescue methods at high altitude, flight under complex meteorological conditions, standard liquids used in aviation and preventive measures to be applied when working with such liquids, principles of ensuring satisfactory conditions during flight from the medical point of view. In this textbook the author also discusses the effects of atomic weapons on the human body and gives some recommendations on protecting it from such effects, and on first aid requirements as encountered in the conditions of operational airforce units. At the end, problems of hygiene and sanitation are dealt with (personal hygiene, infectious diseases and their prophylaxis, first aid for injuries, etc.), to the extent of the syllabus of courses of aviation teaching establishments. /2

This textbook is intended for students of teaching establishments of all types of aviation. It can also be very useful for the test flying and engineering personnel of the Air Force, GVF, DOSAAF and others interested in aviation and aviation medicine.

Since this textbook also contains recommendations on first aid for frostbite and general exposure to cold, burns, accidents suffered as a result of electrical shocks, heat and sun strokes, fainting, drowning, general injuries and fractures, the book is also useful for all types of armed services and for a wide range of Soviet readers.

Conservation of the health of people and their working capacity is one of the most gratifying types of activity. /3

M. I. Kalinin

CHAPTER I

SUBJECT MATTER AND TASKS OF AVIATION MEDICINE

/5

Aviation medicine is a special branch of general medicine. It faces extremely acute problems, namely, of ensuring not only life and working conditions of the flying personnel during flights at high velocities and altitudes and over long distances, but also of selecting people of a satisfactory standard of health for service in aviation, and finally it is also concerned with studying the professional pathologies which may develop amongst flying personnel.

The effects of flight factors on the human body have been studied right from the beginning of air travel. Each new achievement in aviation brought with it new problems for aviation medicine, necessitating study of the changes occurring within the human body under the influence of flight factors, and searching for methods which could eliminate or alleviate the serious effects of some of these factors on the physical state and general health of the personnel.

In Russia, work in this field has been going on for a very long time.

The first Russian who flew repeatedly with an air-sphere which he built himself, was Staff-Surgeon Kashinskoy (Ref. 1) of Lefortov Hospital in Moscow. These flights were made from Neskuchnyy in Moscow on September 24 and October 1, 1805. Flights with scientific aims were continued in /6 1868 by the talented physicist M. A. Rykachev, who together with other physical investigations studied the visibility and audibility in flight, observed his own reactions, etc. M. A. Rykachev was the first to describe the qualities which are necessary in an aerial flight. "Control of the balloon requires all those qualities which seamen have to have: fast reactions, high degree of orderliness, presence of mind, circumspection, concentration and adroitness" - was what M. A. Rykachev wrote (Ref. 2).

In the history of Russian aviation medicine the work and statements of D. I. Mendeleyev are of great interest. He was the first in the world (1875) to make a perfectly clear statement on the necessity of having a hermetically sealed cabin for flight into the upper layers of the atmosphere and to develop schemes for a balloon with a hermetic cabin. He proposed a method for storing and transporting gas by compressing it into steel cylinders, a method still in use for ensuring the oxygen supply of an aircraft. D. I. Mendeleyev also wrote about the necessity of providing "an engine system which is accessible to all, and comfortable." There is reason to believe that, influenced by these ideas of "comfort", elementary hygienic requirements were provided for the first time on the Soviet aircraft "Il'ya Muromets" (1914), while such measures had not yet been taken on foreign aircraft.

D. I. Mendeleyev flew with his air balloon on August 7, 1887.

A number of other Russian scientists flew in air balloons. Each such ascent enriched science with new discoveries.

A number of Russian physiologists and physicians have studied the influence of rarefied atmosphere on the human body; these studies were of great importance for the further development of aviation medicine. As long ago as the last century, Russian investigators studied experimentally the effect of oxygen starvation on breathing, metabolism, central nervous system, etc.

A thorough scientific analysis of the effect of the rarefied atmosphere on breathing was made by I. M. Sechenov (1879) who was the founder of the Russian school of materialistic physiology. /7

It should be pointed out that the first experimental work on the influence of accelerations on living animal and human organisms in Russian and foreign medicines were made long before the emergence of aviation.

Fundamental work on the influence of accelerations on the vestibular organs was carried out by the Soviet scientist V. I. Voyachek.

After the first world war special institutes, schools and laboratories in aviation medicine were formed in many countries of the world, in which outstanding physiologists, hygienists and psychologists worked. After the second world war the network of scientific research establishments on aviation medicine expanded rapidly to keep pace with the rapid developments in aviation.

In Russia aviation medicine flourished under the Soviet regime. A State scientific research institute of aviation and space medicine, laboratories and departments of aviation medicine exist in the Soviet Union; all this permits extensive development of research work and rapid application of the achievements in the field of aviation medicine.

During flight the pilot is subjected to specific conditions which have to be taken into consideration in order to eliminate the untoward effects of the flight factors on the body. These comprise: reduced pressure of the ambient atmosphere; a reduction of the partial oxygen pressure in the inspired air; low temperature of the ambient atmosphere; large centripetal accelerations during acrobatic flights; complexity of aircraft control under rapidly changing flight conditions; high emotional stresses.

Piloting modern aircraft demands accurate and rapid reactions, a rapid evaluation of the continuously changing conditions associated with the high flight velocities.

Furthermore, the pilot has to observe and monitor continuously during flight a large number of instruments and mechanisms, on the basis of which he must perform a multitude of functions often under great nervous and psychological stress. /8

During flights on modern high-speed aircraft, the human body is brought very quickly from ground-level conditions into new conditions which necessitate the finding of new methods for eliminating or alleviating the effects of untoward flight factors on the human body.

At present, aviation medicine possesses methods of investigating the human body which permit comprehensive and thorough study of the changes in the functions of the body under specific conditions of flight experienced in modern aircraft. For such studies aviation medicine uses extensively barometric chambers, thermobarometric chambers, centrifuges, experimental flights, aircraft laboratories, radio, etc. On the basis of the experimental investigations, means have been developed and applied which ensure maintaining the working capability of flight personnel at high altitudes as well as under supersonic flight conditions.

Increasing the height, velocity and range of flights requires continuous improvement of the methods which alleviate the unfavorable effects of flight factors on the human body.

Results of work on aviation physiology and aviation hygiene are of great importance also from the point of view of design calculations which determine the conditions of work of the crew in an aircraft and the physiological possibilities of the human body exposed to these conditions.

At present the development of more modern aircraft is unthinkable without close cooperation between aircraft designers and aviation medicine personnel.

References

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2. Rykachev, M. A. Ascending with an air balloon in St. Petersburg May 20 and June 1, 1873. "Zapiski imperatorskogo russkogo geograficheskogo obshchestva," v. II, 1882, p. 30.

CHAPTER II

BRIEF INFORMATION ON THE ATMOSPHERE /9

The earth is surrounded by an air shell which is referred to as atmosphere. A great variety of physical processes and phenomena are continuously taking place in the atmosphere.

Structure of the Atmosphere

The atmosphere is sub-divided with respect to height into four main layers: 1) troposphere; 2) stratosphere; 3) ionosphere; 4) exosphere.

The troposphere is the lowest and densest layer of the earth's atmosphere. Its thickness over various parts of the earth and during various periods of the year varies: in medium latitudes it extends to 10-12 km above sea level; at the poles it extends to 7-10 km above sea level; and over the equator it extends to 16-18 km above sea level.

The troposphere contains 9/10ths of the entire mass of the atmosphere and almost the entire quantity of water vapor. In this layer there are ascending and descending air currents; powerful cloud formations and mists form here as well as all kinds of precipitations and it is in this layer that all the other weather phenomena take place. A characteristic feature of the troposphere is the steady decrease of the temperature and humidity of the air with height. As an arbitrary boundary between the troposphere and the stratosphere is taken that height above sea level at which there is no further drop in temperature. The change in temperature from the troposphere to the stratosphere is not instantaneous. There is between them an intermediate layer 1 to 3 km thick in which the temperature may increase or even remain unchanged. This /10
intermediate layer is called the tropopause.

The stratosphere is the layer of atmosphere above the troposphere extending to an altitude of about 80 km. The stratosphere consists of highly rarefied air, practically devoid of moisture; it is characterized by almost complete absence of clouds, a high intensity of ultraviolet solar radiation, absence of dust of terrestrial origin and weakening of the turbulent intermixing of the air. Furthermore, quite recently the existence in the stratosphere of a particular temperature regime was proved which will be dealt with later.

The ionosphere is the layer of the atmosphere extending up to an altitude of about 800 km. The ionosphere is characterized by a high degree of ionization of the gas molecules. The high degree of ionization of the upper layers of the atmosphere is explained by the effect of ultraviolet radiation derived from the sun, which is constant in this layer and has an extremely strong dissociative effect on the molecules. To some extent the ionization of the gas molecules is also due to X-rays and cosmic radiation.

The exosphere is the layer above the ionosphere, ranging from 800 to 3000 km above sea level. It is characterized by an extremely rarefied atmosphere: beyond the exosphere begins a dissipation zone which gradually passes into interplanetary space. (Translator's note: This last statement is not in agreement with the view prevailing).

Composition and Pressure of the Atmospheric Air

Atmospheric air is a mixture of various gases. The main gases in this mixture are, volumetrically: nitrogen 78.08%; oxygen 20.95%; argon 0.93%; carbon monoxide 0.03%. The quantity of other gases in this mixture is negligible: hydrogen 0.005%; neon 0.0018%; helium 0.00015%; and traces of krypton and xenon. This composition remains constant up to altitudes of 100-120 km.

Atmospheric air will always contain moisture in the form of water vapors (on the average about 1% by volume). In a hot and humid climate the quantity of water vapor in the air may reach up to 4% and in places with a dry continental climate it may drop during the winter to 0.01% by volume.

The quantity of water vapor in the air decreases with increasing altitude. Some change in this is brought about by cloud formations in which the humidity may approach 100%.

The state of dry air in the stratosphere is distinguished by a very important feature, namely an increase of the total concentration as well as of the relative content of ozone with altitude. Ozone forms in the stratosphere as a result of dissociation of oxygen molecules caused by ultraviolet radiations of the sun and cosmic radiations with subsequent recombination with additional oxygen atoms in the oxygen molecules. In the lower layers of the atmosphere a certain quantity of ozone is formed during lightning discharges. In the atmosphere, ozone is distributed in the form of a scattered layer extending from the ground up to about 55 km. If the entire ozone in the atmosphere were concentrated in the form of a layer at the ground atmospheric pressure, the thickness of the layer would not exceed 2 - 3 mm. /11

The main quantity of ozone is concentrated at altitudes between 20 and 35 km, the maximum concentration being at altitudes of 25 to 27 km. Even here the ozone content is only 0.000004% in volume.

In spite of being present in minute quantities, the role of ozone in the atmosphere is extremely important due to its very intensive absorption of radiations from the sun as well as from the earth. It absorbs the main portion of short ultraviolet spectrum of the sun with wavelengths below $230\,m\mu$, which have very strong biological activity. In addition to the utraviolet rays, the ozone absorbs a certain portion of the visible and infrared spectra.

The heating up of the ozone brings about a considerable increase in the temperature of the higher layers of the atmosphere.

The quantity of ozone varies with latitude, reaching minimum at the equator and a maximum in the polar regions. As regards the annual fluctuations, the maximum ozone content occurs during the spring; the minimum during the fall.

An ozone concentration in the air of 0.0001 mg/liter is considered admissible. (Translator's note: According to current views ozone is considerably more toxic than the figure quoted by the author. The low toxicity figures of the past are attributed to poor analytical techniques and frequent mistaking of various forms of active oxygen for ozone). A higher concentration of ozone causes irritation of the mucous membranes of the upper breathing canals (nasal passages) and of the lungs.

An atmosphere containing ozone in quantities of thousandths or hundredths of a percent will bring about disintegration of rubber and intensive corrosion of metals.

In addition to gaseous components, the atmosphere also contains a certain quantity of suspended solid particles in the form of dust, both of organic and inorganic origin, which passes into the atmosphere in great quantities from the surface of the earth. The quantity of dust in the atmosphere decreases with altitude, and dust of terrestrial origin /12
is almost completely absent at altitudes of 7 to 8 km. This can be seen from Table 1, below.

Altitude above sea level, m	10	1000	2000	3000	4000	5000	6000	7000
Number of dust particles per cm^3	45000	6000	700	200	100	50	20	6

Table 1

Study of the aurorae indicates that at altitudes up to 100-120 km the composition of the atmosphere is the same as it is at ground level. However, at altitudes of several tens of kilometers and higher the molecules of oxygen and of nitrogen become more and more dissociated as a result of the extremely intensive ultraviolet radiation of the sun and, finally, at higher altitudes they transform into the completely ionized state.

In the same way as all other substances subjected to gravity, the atmospheric air exhibits a weight. At sea level and at a temperature of 0° C, one cubic meter of dry air weighs about 1.3 kg and therefore the mass of air above the surface of the earth is attracted to its center and exerts a pressure on the earth's surface as well as on any other object located on the surface of the ground and in the air.

At sea level the air pressure per 1 cm^2 of the surface equals 1.033 kg, and this pressure is referred to as atmospheric pressure. The column of air from sea level up to the upper boundary of the atmosphere, with an area at the base of 1 cm^2, balances in weight a column of mercury with the same base area and a height of 760 mm, located at a latitude of 45° and at a temperature of 0° C. This is the reason why atmospheric pressure is usually expressed in terms of the length of mercury column in millimeters.

At sea level the atmospheric, or as it is usually called the barometric, pressure corresponds on the average to a pressure of a mercury column of 760 mm height. However, the magnitude of this pressure is not constant. It varies within wide limits with the geographical location, with the period of the year and with the weather. Extreme values of atmospheric pressure observed up to the present are respectively 680 and 802 mm. The total pressure of the atmosphere is composed /13
of the partial pressures of the constituent gases.

Altitude	Pressure	Temperature
1000	674.10	+8.50
2000	596.10	+2.00
3000	525.79	-4.50
4000	462.26	-11.00
5000	405.00	-17.50
6000	353.77	-24.00
7000	307.87	-30.50
8000	266.86	-37.00
9000	230.40	-43.50
10000	198.10	-50.00
11000	169.69	-56.50
12000	144.80	-56.50
14000	105.60	-56.50
16000	77.1	-56.50
18000	56.2	-56.50

Altitude	Pressure	Temperature
20000	41.0	-56.50
22000	31.0	-56.50
25000	19.1	-56.50
28000	12.0	-56.50
30000	9.0	-56.50
32000	6.2	-35.2
35000	4.5	-26.8
40000	2.0	-12.0
45000	1.2	+3.7
47000	0.9	+8.6
50000	0.6	+9.7
53000	0.43	+9.7
75000	0.015	-72.7
90000	0.006	-76.1

Table 2

Table of International Standard Atmosphere

Under the term partial pressure of the gas we understand the fraction of the pressure of the given gas in the gas mixture, i.e. the pressure which this gas would exert if the entire volume taken by the mixture were taken by this gas alone. The total barometric pressure decreases gradually with altitude; this is due to the decrease in height and density of the column of air located above it. Thus, for instance, at an altitude of 12 km one cubic meter of air weighs 319 g, i.e. a quarter of the corresponding weight at sea level. At an altitude of 40 km it weighs only 4 g. /14

Side by side with the decrease of the total barometric pressure the partial pressures of all the gases contained in the air will also decrease. Since the composition of the air does not change with altitude, the partial pressure of any gas at any altitude may be easily calculated if the total barometric pressure for the given altitude is known, by means of the following formula:

$$P = \frac{C \cdot B}{100},$$

where: P - partial pressure of the gas; C - percentage content of the gas in air; B - total barometric pressure.

From the point of view of man, the most important factor is the partial pressure of the gas. Of all the gases in the air oxygen is the most important for the activity of the human body. Without oxygen, (human - Translator) life cannot exist. In spite of the constant oxygen content of the air at high altitudes, its physiological activity will vary due to a decrease of its partial pressure, see Table 3.

Altitude, m	Total barometric pressure	Partial oxygen pressure
0	760	159
1000	674	141
2000	596.10	125
3000	525.79	110
4000	462.26	98
5000	405.00	85
6000	353.77	75
7000	307.87	66
8000	266.86	56
9000	230.40	48
10000	198.10	42
11000	169.69	36
12000	144.80	36

Table 3

Change in the Partial O_2 Pressure as a Function of Altitude

Examples of calculating the partial pressure of oxygen at various altitudes: /15

For the altitude of 10,000 m, $P = \frac{21 \cdot 198}{100} = 42$ mm Hg.

For the altitude of 6,000 m, $P = \frac{21 \cdot 354}{100} = 74$ mm Hg.

At ground level, $P = \frac{21 \cdot 760}{100} = 159$ mm Hg.

The amount of water vapor in the atmosphere which determines the degree of air humidity is not constant. It depends on a number of factors and particularly on the air temperature. Usually, the higher the air temperature under given conditions, the greater the amount of water vapor retained in the air.

We distinguish between absolute and relative air humidities.

Absolute air humidity is the quantity of water vapor contained in 1 m^3 of air under given conditions expressed in grams or in mm of mercury. The air can absorb only a certain quantity of water vapor at a given temperature. Air containing the maximum quantity of water vapor is referred to as saturated.

Relative air humidity is the ratio of the quantity of water vapor contained in the air to the quantity which would saturate the air at the same temperature.

The relative air humidity is expressed as a percentage.

The relative air humidity changes with altitude and depends on the weather. When it is cloudy the relative humidity is higher and at cloud level it reaches 100%; behind the clouds the humidity decreases. In clear weather the relative humidity decreases with altitude.

Solar Radiation

Solar radiation is the flux of radiation energy of the sun incident upon the surface of the earth. The solar spectrum contains wavelengths from 0.006 to 2300 mμ. Passing through the earth's atmosphere, part of the solar radiation is reflected; another part is scattered and absorbed by the molecules of the air, water vapor and dust particles in the atmosphere. The greatest changes occur in the ultraviolet part of the /16 spectrum. The very short wavelengths (from 0.006 to 290 mμ) do not reach the surface of the earth and are fully absorbed by the ozone layer located at an altitude of 20 - 40 km. The infrared sun rays are also absorbed by the water vapor in the atmosphere. Consequently, the higher the content of water vapor in the atmosphere, the lower will be the infrared radiation reaching the earth's surface. The intensity of solar radiation flux at the upper limit of the atmosphere equals 1.94 calories per cm^2 of area per minute, while at the ground surface it does not exceed 1.52 calories. With increasing altitude, the intensity of solar radiation, the ultraviolet as well as the infrared particles, increases. The ultraviolet radiation increases on an average by 3 - 4% for each 100 m of increase in altitude.

Within permissable limits solar radiation has a very favorable influence on the human body, stimulating normal physiological processes. The general feeling of well-being increases under the influence of the sun's radiation and so does the working capacity of the human body.

It is well known that people feel considerably less exuberant on cloudy days.

Particularly favorable is the effect on the human body of the "biologically-active" short-wave part of the sun's spectrum of a wavelength of 300 - 365μ.

In addition to solar radiation, cosmic ray showers penetrate incessantly the atmosphere and the surface of the earth. Although a major part of the cosmic ray components is absorbed by the atmosphere, a certain secondary phenomenon can be detected at sea level. Numerous observations during the past few years indicate that the usual level of cosmic radiation at sea level and at altitudes up to 20,000 - 25,000 m does not have an adverse effect on living beings, even if they remain at these altitudes for many dozens of hours. However, prolonged exposures at altitudes in excess of 27,000 m, where cosmic rays have higher energies, may cause ionization of the molecules of the living tissues and have untoward effect on the living matter.

Temperature

A large part of the sun's radiation that reaches the surface of the ground is absorbed by it and becomes transformed into heat. The ground air-layer is heated by means of conductivity and convection. /17
The heated air becomes less dense and lighter and therefore rises and moves away from the heated surface of the ground to be replaced by colder masses of air which move downwards. The air expands on rising and penetrating into the regions of reduced pressure. A certain amount of heat energy is expended in performing this operation and therefore the air temperature drops; as the air rises from the ground surface its temperature drops gradually (within the limits of the troposphere, by an average of 0.65° C for each 100 m of increase in altitude). This quantity is referred to as the "vertical temperature gradient of the atmosphere." The changes in temperature of the troposphere are given in Table 4.

Altitude, m	Temperature, °C
0	+15
1000	+8.5
2000	+2.0
3000	-4.5
4000	-11.0
5000	-17.5
6000	-24.0
7000	-30.5
8000	-37.0
9000	-43.0
10000	-50.0
11000	-56.0
12000	-56.5

Table 4

However, the drop in temperature is not always regular; at altitudes up to 2 km deviations can be observed from the temperature calculated on the basis of the vertical temperature gradient. In some cases, a rise and not a fall in air temperature with altitude can be observed. This phenomenon is referred to as "inversion." Most frequently, inversion is due to intensified radiation from the ground surface and turbulent intermixing of the air masses. While moving upwards the heated air cools down and therefore it can rise only to a certain height, at which its further rise or further drop in temperature ceases. This height represents the boundary between the troposphere and the stratosphere. The /18
temperature at this boundary reaches -56° C in temperate latitudes, and falls down to -70 to -80° C at the equator. This temperature remains constant in the stratosphere up to the altitude of about 30 km. However, from this altitude upwards the temperature starts to rise due to the heating of the ozone by the absorbed ultra violet radiation, so that at 40 - 50 km the air temperature reaches +40 to 50° C. The temperature drops again above 50 km, reaching the lowest temperatures of the entire earth's atmosphere (-70 to -80° C) at the upper boundary of the stratosphere. In the ionosphere the temperature increases again to 150° C at an altitude of 120 km, and up to 1200° C at an altitude of 200 - 250 km. It is pointed out that due to the extremely rarefied air at these altitudes the term "gas temperature" assumes a completely different meaning from that pertaining to the earth surface. The air temperature in these layers of atmosphere reflects only the velocity of movement of the gas particles. Heating of (solid) bodies will occur as a result of absorption of the radiation of the sun.

CHAPTER III

BRIEF INFORMATION ON ANATOMY AND PHYSIOLOGY

Anatomy and physiology belong to the biological sciences which are concerned with the study of living organisms. Anatomy is the science of external shapes and internal structure of the organism and physiology is the science of the functions, i.e. the living functions of the individual organs and of the organism as a whole. /19

According to the views of I. P. Pavlov, the most important task in physiology consists of finding methods of controlling the functions of the organism.

It is extremely important for a pilot of modern aircraft to have a clear concept of the structure and basic functions of the human body; this plays an important role in the solution of problems relating to rational organization of work of the flight and engineering Air Force personnel.

The human body is a complicated entity. All the cells, tissues and organs of the body are interconnected. In this respect the nervous system plays a leading role. Even the tiniest part of the body contains branched-out nerve fibers. Stimulation of nerve endings in one organ influences the activities of the others through the central nervous system. Thus, for instance, nerve endings of any part of the skin stimulated by pain may bring about a contraction of a certain group of muscles, change the heart function, impede breathing, etc. The activity of all the organs and all the life processes in the body is continuously monitored and controlled by the central nervous system. Interconnection between cells, tissues and organs is also effected by chemical means through the blood and the lymph. Various substances that form during /20
the functioning of the organs enter the blood and flow through the entire body; thereby, substances produced by one organ may bring about or maintain the activity of other organs. Thus, for instance, the substances which enter the blood from the adrenal glands affect the operation of the heart and intestines. However, the chemical interaction between the individual organs is also controlled by the central nervous system. "There is not a single part in the human body which can exist by itself without any interrelation with the other parts; however, not a single one of the parts of our body has an important a link with the others as the brain" (Ref. 1).

Study of the organism as a whole includes also the inseparable link between the psychic and physical functions. This means that the psychic activity represents a function of highly-organized matter - the brain.

The structure and the functions of the body are always adapted to specific conditions of the ambience. Any change in the conditions of existence of the body causes a change in function of its organs.

"The body - without an external medium to maintain it - could not exist; therefore, in the scientific definition of the body it is necessary to include the medium influencing it, since without the latter the body could not exist" (Ref. 2). This is what was said by I. M. Sechenov. Consequently, the structure and the living functions of the body can only be understood when studying it in conjunction with the conditions of existence.

With respect to man, it is necessary to consider not only the biological but also the social laws which, to a considerable extent, determine his development and activities.

Cells and Tissues

The human body has a cellular structure and consists of a large number of cells. "The living organism represents an extremely complex system, consisting of an almost infinite series of parts which are linked both with each other as well as with the surrounding nature..." (Ref. 3).

As regards shape, size and structure, the cells are greatly divergent. According to present-day views each cell is a microscopically /21
small organ of a complex multicellular organism in which life processes take place and certain vital functions are performed. Each living cell obtains from the external medium the nutritive substances it requires as well as oxygen and it releases into the external medium the waste products (carbon dioxide, etc.) formed during the process of performing the vital functions. Thus, between the cell and the medium surrounding it, there is a continuous interchange without which life could not exist. "Life" - said Engels - "is a method of existence of protein bodies, the important factor being the continuous interchange of matter with the nature surrounding them and if this interchange stops, then so will life, which will lead to decomposition of the protein" (Ref. 4). Cells which perform certain life functions combine to form the main groups of tissues - in the first instance, nerve tissues, bone, muscles and epithelial tissues.

Organs and Their Systems

The human body consists of organs and tissues which have a certain structure and fulfill one function or another. By its rhythmical contractions the heart ensures movement of the blood along the vessels; the lungs ensure the exchange of gases between the human body and the external medium, etc. Usually, each organ will contain different quantities and ratios of tissues of all the four basic groups.

In accordance with the main functions of the human body and of living organisms, all the organs and tissues can be grouped into the following systems: musculoskeletal, circulatory, respiratory, digestive, excretory and nervous system, sensory organs, endocrine glands and reproductive organs. The musculoskeletal system comprises the bony skeleton and the striated muscles; the circulatory system comprises the heart and blood vessels. The respiratory system comprises: larynx, trachea, bronchi and lungs. The digestive system is formed of the esophagus, stomach, intestines, pancreas and liver. The excretory system comprises: the kidneys, ureter and bladder. The nervous system is formed of the brain and spinal cord, the sensory and motor nerves.

Distinguished by their structure and functions and possessing a /22
certain independence, all the systems of organs function in close coordination with each other. The human body cannot survive without any of these systems or without close interconnection between them.

The Nervous System

The nervous system plays a major role in the life and activity of any organism. Its important role in all vital processes of the human body and its interaction with the surrounding medium were conclusively proved by the work of the great Russian physiologists, I. M. Sechenov and I. P. Pavlov.

The idea of nervism, i.e. the idea of the leading role of the nervous system in the reaction of the organism as a whole, has been developed to its highest level in the teachings of I. P. Pavlov on the higher nervous activity and forms the materialistic scientific basis of Soviet physiology, biology and medicine.

Due to the nervous system the organism perceives changes which occur around it and reacts actively to these. Furthermore, the nervous system regulates and coordinates the functions of the various organs, tissues and cells, adapting them to the continuously changing conditions of the external medium.

The basis of the nervous system is formed by nerve cells and their processes.

The entire nervous system is subdivided into a central part consisting of the brain and the spinal cord and a peripheral part to which /23
belong the cerebral and spinal nerves.

The brain (Figure 1) is located in the cavity of the skull and the spinal cord is located in the vertebral canal.

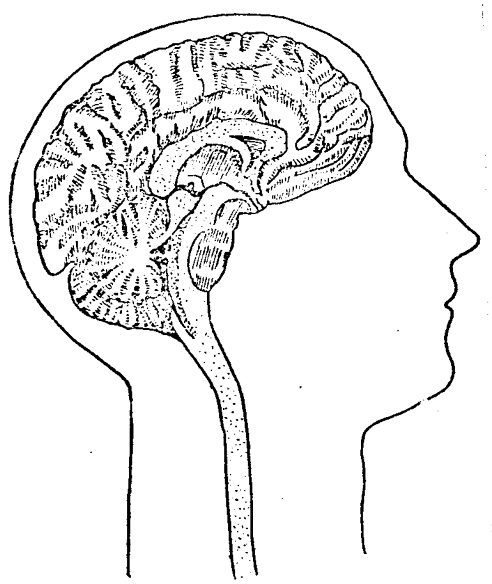


Figure 1. Central Nervous System (Brain).

A large number of nerve fibers emanate from the brain and the spinal cord which penetrate to all parts of our bodies. There is a distinction between motor and sensory nerve fibers. The first transmit impulses from the central nervous system to the organs and to the tissues, causing them to function; the second transmit impulses from all the organs and cells into the central nervous system. In addition to the motor and sensory function, the nervous system also performs the so-called trophical function (from the word "trophics" - nutrition). The trophic nerves influence the body metabolism and regulate the nutrition of the tissues and the organs, which is of enormous importance for the maintenance of the vital functions of the body.

The Brain

The brain is sub-divided into five sections: two hemispheres (right and left); the diencephalon; the mesencephalon; the medulla oblongata and the cerebellum. The greatest part of the brain is formed by the hemispheres. The surface of the brain is speckled with fissures and convolutions. The outer section of the large hemispheres is called the cortex. The cortex covers all the fissures and convolutions of the brain. This area covers 20 m^2. It consists of a large quantity (about 16 billion, i.e., 16,000 millions) of nerve cells which differ in structure and function. The cerebral cortex is the highest section of the central nervous system, without which the psychic and all the complex activities of man would not be possible.

The investigations of numerous scientists have shown that in the human cerebral cortex there are sections or centers which perform specific functions. For instance, the occipital sections contain the centers of vision, the temporal sections contain the centers of hearing, etc. I. P. Pavlov has tendered this interpretation. According to his teachings the cerebral cortex regulates, monitors and unifies the activities of the entire body in its interaction with the external and internal environment. For regulating the activities of the body, it is necessary that various stimuli (signals) should reach the brain from the outside as well as from internal organs.

/24

For perceiving stimuli there are specially adapted nerve endings, the so-called receptors, which penetrate into all the tissues and organs.

The sensory nerves are distributed in the skin as well as in the eyes, ears, olfactory organs and taste buds which sense various pain, temperature, tactile, light, chemical and other sensations arriving from the external environment. The body is continuously linked with the outside medium by these receptors (exteroceptors). Those receptors which are situated in the muscles, tendons and joints, i.e. the so-called proprioceptors, send stimuli which arise in these in conjunction with the displacement of the human body in space and changes in its position. The resulting sensations are called musculo-articular sensations.

Finally, the stimuli arising in internal organs are transmitted to the cortex from the receptors in the heart, lungs, liver and other internal organs (so-called enteroceptors). The cortex is connected to the outside world and the internal organs of the body by means of this type of receptor.

According to the teachings of I. P. Pavlov, the connection between the cortex and the external and internal enviroment is effected by means of so-called analyzers which enable man to perceive the outside world. Each analyzer consists of three sections: 1) the receptor, i.e., that perceiving stimuli from the external medium; 2) conducting pathways with intermediate centers, through which the perceived stimuli pass; and 3) the cortex, the cells of which transform the stimuli into perception. Thus, for instance, the visual analyzer contains as receptors the rods and cones of the retina. The conducting path is the optic nerve with sub-cortical centers in the mesencephalon and, finally, the center in which the optic stimuli are transformed into perception is the optic center located in the occipital lobe of the cortex.

By using the term "analyzers", I. P. Pavlov emphasized their importance in the human body for analyzing phenomena of the external and internal environment.

The main part of the analyzer is formed by its cerebral section, located in the appropriate regions of the cerebral cortex. /25

The cerebral cortex was referred to by I. P. Pavlov as a complex analyzer. The different signals passing into it from the outside are not only analyzed (disintegrated and sorted) but also synthesized, i.e. connected, compared, etc. Both the synthesis and the analysis take place in the nervous cells of the cortex. Thus, the higher analysis and synthesis of all the complex phenomena of life takes place in the cortex.

As a result of the analytic and synthetic function of the cerebral cortex, the entire body is unified into a single whole as regards interaction with the surrounding medium. The cerebral hemispheres are more recent additions to the central nervous system, reaching the highest development in man.

The so-called brain stem is of an older vintage. This section is an intermediate link between the cerebral cortex and the spinal cord. Together with this it also contains independent vitally important nerve centers.

The Spinal Cord

The spinal cord is located in the vertebral canal. It is 40 - 45 cm long; the average diameter of a cross-section reaches about 1 cm. The spinal cord consists of nerve cells and nerve fibers. Thirty-one pairs of spinal nerves emanate from the spinal cord, which gradually branch out into fine networks penetrating all the tissues and organs. The spinal nerves contain motor and sensory fibers. Along the motor nerve fibers impulses spread from the center to the periphery (muscles), which cause contraction of the muscles, and along the sensory nerve fibers various stimuli, perceived by the nerve endings located in the tissues and organs, pass from the periphery to the center.

Thus, the spinal nerves connect the periphery of our body (skin, muscles, etc.) with the central nervous system.

The Activity of the Nervous System /26

The basis of the activity of the nervous system is a so-called "reflex". By reflex, we understand the reaction of the body, its response to any stimulus - which is effected by the central nervous system. For instance, when the hand is pricked or burned, it will withdraw quickly. This is explained by the fact that when pricked, the nerve endings in the skin are stimulated; the stimulus travels from these ends along the peripheral sensory nerve into the spinal cord, where the stimulus is switched from the sensory to the motor cells of the spinal cord. From there, the stimulus is passed along the motor spinal nerve to the hand muscles. This is the path or arc of a reflex. When the impulse is passed to the muscles, they contract, as a result of which the hand pulls away.

According to the teachings of I. P. Pavlov, there are unconditioned and conditioned reflexes. Unconditioned reflexes are inborn and are transmitted to offspring (inherited). Those reflexes which people acquire during their individual lives as a result of interaction with their environment are referred to as "conditioned".

The teachings of I. P. Pavlov on the conditioned reflexes played an important role in the understanding of the basic laws governing the higher nervous activity of animals and man.

Throughout its entire lifetime the body is continuously in contact with the surrounding world. In order to survive it has to adapt itself to its environment and be in constant touch with this environment.

The link of the body with the external environment is materialized by unconditional reflexes and particularly by the formation of new so-called conditioned reflexes. For instance, if food enters the mouth then the contact between the food and the mucous membrane of the oral cavity will stimulate the nerve endings in these tissues; as a result the secretion of saliva will begin, which is necessary for digesting the food. This unconditioned reflex will always occur when food enters the mouth. Furthermore, if each intake of food by an animal is preceded by any other indifferent stimulus, for instance a bell or the lighting-up of an electric lamp, then after multiple repetitions of this condition (the action of the light or the bell) the secretion of saliva will occur after the mere ringing of the bell or lighting-up of the lamp, even before taking in any food. If the lighting-up of the lamp or the ringing of the bell is not accompanied by the serving of food, then there will be no secretion /27
of saliva.

Conditioned reflexes are characteristic not only for animals but also for man. One of the examples of this is the known fact of intensified salivation on seeing a lemon or sour apple.

Conditioned reflexes are of great importance in the life of man since they form a link with the outside world by establishing temporary nerve connections as well as inhibition of those connections, which have lost their importance.

I. P. Pavlov has shown by means of conditioned reflexes the extremely important function of the cerebral cortex - its signaling activities. For life it is very important that the cortex should signal not the event which has already occurred, but the one which precedes it and warns us. Thus, the body is better prepared to resist external or internal effects.

With the progress of time, temporary connections are created and reinforced in the cerebral cortex, which man gains by individual experience and which make his life considerably easier.

Man and animals obtain signals from the outside world through their organs of vision, hearing, smell, etc.

The mechanism which ensures the obtaining of signals through vision, hearing and smell is referred to by I. P. Pavlov as the first signal system of reality. For man, the first signal system is of great importance. However, as I. P. Pavlov has shown, man, unlike the animals, has asecond signal system, with the aid of which he preceives not only direct acoustic, visual and other impulses, but can also create an image of these by words, with the help of letters, pictures, etc.

The second signal system of reality is of predominant importance to man. I. P. Pavlov wrote: "In the developing world of living beings an extraordinary addition to the mechanism of nervous function occurred, at the phase when man developed. For the animal, reality is signaled almost exclusively by the stimuli and their traces in the cerebral hemispheres, which stimuli arrive directly into the special cells of the optic, acoustic and other receptors of the body. These are the stimuli /28 which we are carrying within ourselves, as impressions, sensations and conceptions of the external environment surrounding us, including both nature in general and our social environment, with the exception of the spoken or written word. This is the first signal system of reality, a system which we have in common with the animals. The world, however, represents a second signal system of reality, specific for us, which system consists of signals acting for the signals of the first system" (Ref. 5).

Analyzers (Sense Organs)

The ability of the central nervous system to analyze phenomena in the external and internal media is one of its most important functions. According to I. P. Pavlov, analysis is the center of gravity of the functioning of the nervous system.

Under the influence of stimulation, a process of excitation arises in the receptors and the stimuli travel along the nerve fibers to the cerebral cortex, where optic, acoustic, gustatory, pain or any other sensations arise, depending on which receptors were stimulated and into which parts of the cortex the excitation arrived.

Any sensation can occur only in the presence of receptors, conducting nerve fibers and the appropriate section of the cerebral cortex. This system, the activity of which secures the analysis of objects and phenomena of the outside world, was designated by I. P. Pavlov as analyzer.

Consequently, under analyzers we understand a definite system which ensures reception of a stimulus, excitation and preception.

Visual Analyzer

The visual analyzer is of extreme importance in the life of man and in the inter-relations with the outside world. By means of the sense of sight we recognize the shape, size and color of an object and the direction and distance at which it is located from us. The visual analyzer comprises the eye, the optic nerve and the optic center located in the occipital lobe of the cerebral cortex.

The eye represents a complex optical system. The ball of the eye has the shape of a sphere which is covered with three membranes (Figure 2). /29

The external thick membrane is called the sclera, its frontal transparent part is called the cornea. The cornea is the only place in the sclera through which light rays can penetrate into the eyeball.

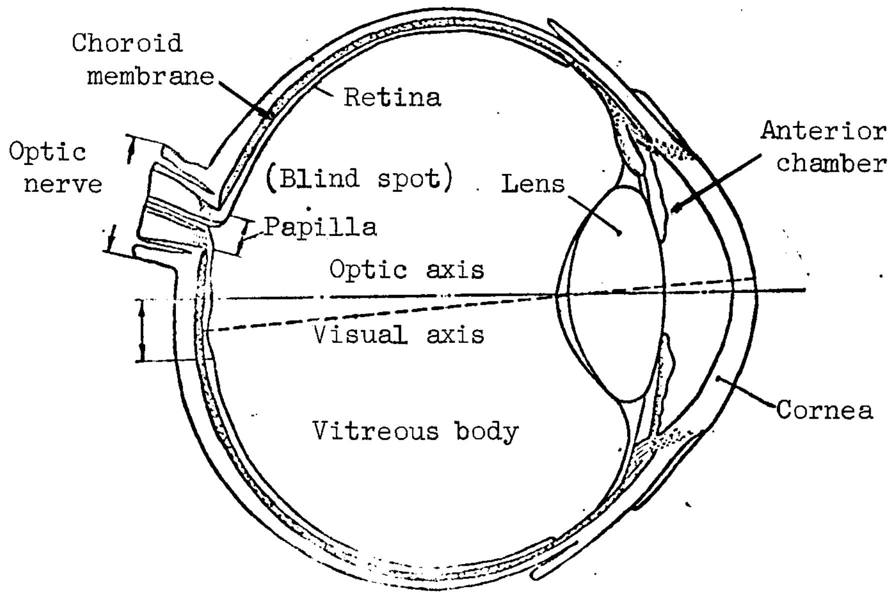


Figure 2. Cross-section of a Human Eye

Underneath the sclera there is a second membrane called the choroid, which is amply supplied with blood vessels feeding the eye. The frontal part of this vascular membrane, situated behind the cornea, is called the iris. In the center of the iris there is an opening called the pupil. The iris plays the role of a diaphragm.

At the rear of the iris against the pupil the lens is located; this can be compared with a biconcave optical lens. Behind the lens there is

a vitreous body which fills the entire eyeball. The cornea, the lens and the vitreous body are transparent; they form the refractive media of the eye. On penetrating into the eye, light rays pass through all three /30
refractive media and fall onto the internal membrane of the eye - the retina. This lines only the rear half of the eye and contains light-sensitive receptors - rods and cones. Each eye has about 130 million rods and about 7 million cones.

The rods contain a photochemical substance - rhodopsin (visual purple).

The cones should contain three photochemical substances. The sensitivity of each of these depends on the degree of concentration.

The cones are distributed primarily in the central part of the retina (opposite to the center of the pupil on the visual axis). The center of the retina contains a depression (called the yellow spot) which contains only cones. From the center of the retina towards the periphery the number of cones decreases.

Rods exist exclusively on the periphery of the retina.

Each cone is connected to a thin nerve fiber and these fibers, grouped as the optic nerve, lead ultimately to the optical center located in the occipital lobe of the cortex.

Several rods (about 100), distributed at various spots of the retina, are also connected to a single optical nerve fiber, which forms part of the optical nerve and leads to the optical center.

The light penetrating into the eye acts on the photochemical substance of the individual retina elements (rods and cones) and decomposes it.

After reaching a certain concentration, the products of decomposition stimulate the nerve endings located in the rods and cones. The resulting impulses travel along the fibers of the optical nerve into the brain cells of the optical center located in the occipital lobe of the cerebral cortex and cause a sensation of light, color, shape and size of an object.

There is a considerable difference between the functions of the rods and cones.

The rods ensure the so-called "daylight vision", since they are capable of perceiving stimuli only if the object has a sufficiently high illumination, while "night vision" is made possible by means of the cones of the retina which react to weak illumination.

The second difference between the functions of the rods and cones consists in the fact that "photopic vision" is sharp and permits distinguishing fine detail; while scotopic (night) vision, by means of the cones, is much duller and does not permit distinguishing fine detail. /31

In fact, when vision is materialized by means of the cones, the cells of the cerebral cortex receive impulses from the same point of the retina on which the image of the viewed fine detail has fallen.

On the other hand, when the vision is by means of the rods of the retina, the impulses into the cerebral cortex are received simultaneously from numerous points of the retina on which the images of various elements of the viewed space fall but in this space individual fine detail cannot be distinguished.

A third difference between the functions of the cones and the rods is that color vision is effected through the cone system of the retina.

The rods do not perceive color and give an achromatic image and, therefore, visual perception through the rod system of the retina is colorless and achromatic; on the other hand, visual perception through the cones is clear and chromatic.

Visual acuity. The eye permits judging the spatial relations between objects. In order to see the shape of an object it is necessary to distinguish its contour, its boundaries. This ability of the eye is characterized as visual acuity. The visual acuity is measured as the minimum angle at which two points can be seen separately. In practical terms the visual acuity is determined by means of objects viewed from a certain distance (5 m) which produce in the eye an image under an angle of 0.5 to 10'.

The Oculomotor System

The movement of the eye is accomplished by means of three pairs of muscles which rotate the eyeball in its orbit. The effect of the muscles of the two eyes is coordinated in such a way that one eye cannot move without the other. As a result of this the visual axes of the two eyes are always directed towards the same focal point.

When viewing nearby objects the visual axes are at an angle to each other, while when viewing infinitely distant objects they become parallel.

Muscle equilibrium and the relative position of the eyes is ensured by appropriate tension and relaxation of all the eye muscles. /32

Numerous points of a viewed object produce images simultaneously in both eyes but we do not perceive a twin image, only a single image at a specific place.

Estimation by sight. Estimation of distances by sight is referred to as estimation by sight. It is of great importance since it permits distinguishing nearby and distant objects. In flying the estimation by sight is of very great importance. The correctness of evaluation of distances depends on the muscle system of the eye and the state of the organ of vision as a whole.

Auditive Analyzer (Hearing Organ)

The main function of the auditive analyzer consists in the perception of sound oscillations, i.e. of mechanical oscillations of particles of the surrounding medium at frequencies between 16 and 20,000 oscillations per second.

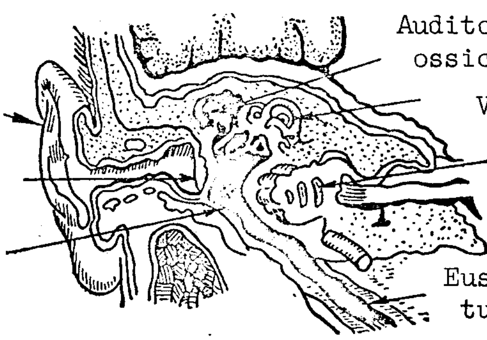


Figure 3. Schematic Section of the Human Ear

The ear is the receptive part of the auditive analyzer. It can usually be sub-divided into three parts: external, middle and inner (Figure 3). The external ear consists of the auricle and the external auditory meatus. The internal end of the external auditory meatus is closed by an elastic membrane called the tympanic membrane, which separates the external ear from the middle ear.

Immediately behind the tympanic membrane there is the middle ear cavity which contains the so-called auditory ossicles: malleus (hammer), /33 incus (anvil) and stapes (stirrup). The system of auditory ossicles serves for the conduction of sound oscillations from the tympanic membrance into the inner ear where the special organ for receiving auditory stimuli, the organ of Corti (named after the Italian scientist Corti) is located. The auditory ossicles called stapes (stirrup) is similar in shape to a little stirrup and is fitted into the so-called oval window of the internal ear, closing the transmission system for sound oscillations from the tympanic membrane to the inner ear.

The middle ear cavity communicates with the nasopharyngeal cavity by means of the Eustachian tube - a special device through which air passes into the cavity of the middle ear during swallowing.

The internal ear is distinguished by the most intricate arrangement of structures. It consists of three parts: vestibular sacs, cochlea and three semicircular canals. All these three parts are distributed in the body of the temporal bone of the skull, forming a complicated bony labyrinth inside which there is a membranous labyrinth, the shape of which is an exact replica of the former. The vestibular sacs and the semicircular canals receive stimuli, which arise as a result of change in the position of the body in space. The labyrinth is filled with a liquid.

The cochlea is a spirally-coiled duct. Every oscillation of the tympanic membrane and of the auditory ossicles brings about a movement of the liquid which fills the cochlea. The cochlea contains the so-called basilar membrane, which is formed by over 20,000 transversely-strung fibers of various lengths, which are reminiscent of strings. The organ of Corti extends throughout the entire length of the basilar membrane; this organ is a physiological instrument for perceiving auditory stimuli. The most important part of the organ of Corti consists of the so-called hairy sensitive cells which have very fine hair. These cells are receptors which receive sound stimuli.

Sound waves from the neighboring medium penetrate into the external ear canal, bring the tympanic membrane into oscillation and via the auditory ossicles these oscillations are transmitted into the cavity of the cochlear duct of the inner ear. The oscillations of the fluid in the cochlear duct bring into motion the fibers of the basilar membrane of the cochlear duct in resonance to those sounds which are transmitted to the ear from the outside medium. The fibers, while oscillating, /34
bring into motion the cells of the organ of Corti which are located on it. As a result, a nervous impulse is generated which is conducted into the appropriate section of the cerebral cortex where the appropriate auditive perception is synthesized.

The Vestibular Analyzer

The peripheral part of the vestibular analyzer is situated in the vestibular sacculi and in the semicircular canals of the internal ear (Figure 4).

On the internal surface of the sacculi, groups of special cells can be seen. One end of these cells is narrowed and ends in short hairs which are turned towards the cavity of the sacculus. The hairs are covered by a great number of very small lime crystals, called otolith membrane (Figure 5).

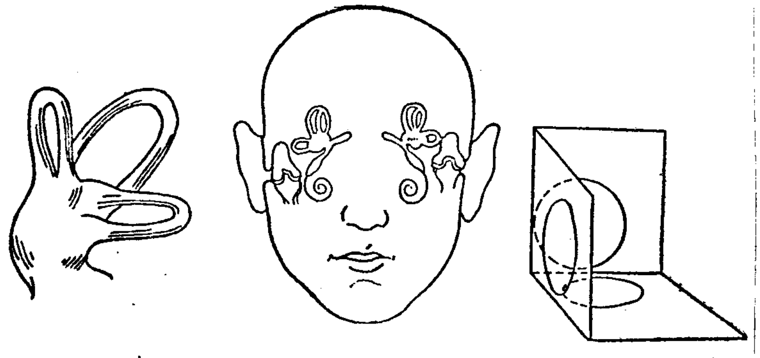


Figure 4. Scheme of the Vestibular Apparatus

If the position of the head or the whole body changes in case of vibration or of acceleration or deceleration of a rectilinear movement, the otolith membrane moves away and exerts a pull on the hairs of the sensory cells lying underneath; this induces a flow of nervous impulses to the medulla oblongata and from there to the cerebellum and the cerebral cortex. Under the influence of these impulses reflexes develop which change the muscular tonus of the skeletal muscles, thus securing the maintenance of the normal position in space of the body and its parts.

The semicircular canals are narrow canals of semicircular shape situated in three mutually perpendicular planes. /35

The cavity of the canals is filled with a liquid which moves whenever a rotatory movement is accelerated or decelerated.

Movement of this liquid serves as stimulus which is perceived by the nervous cells situated along the walls of the dilated ends of the canals. Movement of the liquid within the canals induces nervous impulses in these cells, which impulses proceed to the brain. Having reached the brain, the impulses from these semicircular canals produce a number of reflexes which help to form the so-called spatial sensation, i.e. help to establish and to preserve the appropriate position of the body in space.

Impairment of the function of the vestibular apparatus (the vestibule and the semicircular canals) may cause the feeling of vertigo and nausea. The normal function of this organ is particularly important for airmen whose profession entails frequent changes of the body position in space and continuous acceleration or deceleration of rotatory or rectilinear movements. /36

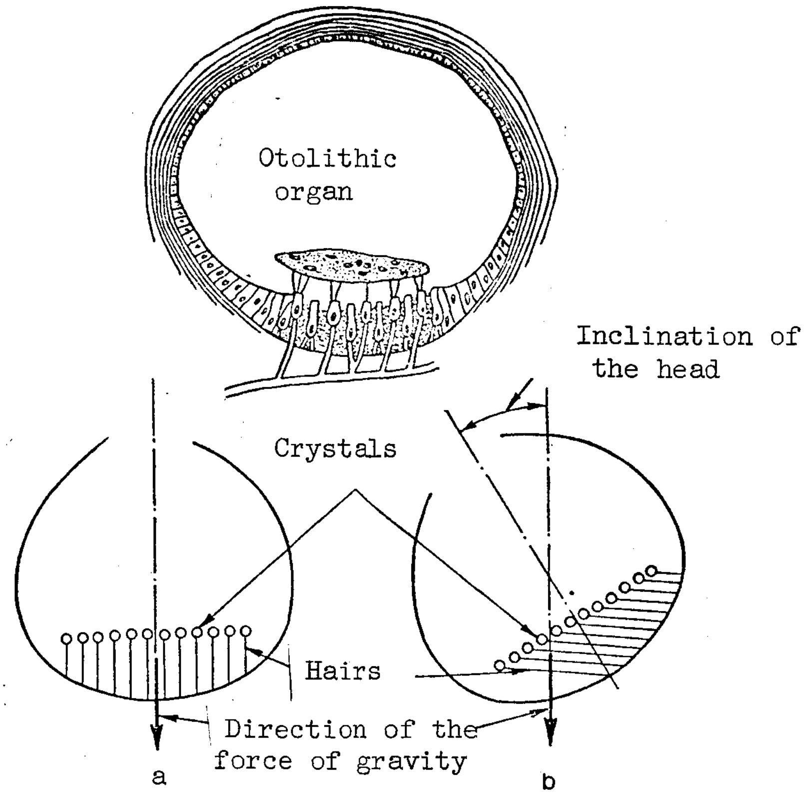


Figure 5. Scheme of the Otolith Apparatus

The Motor Analyzer

The so-called muscle-joint sensation plays a very important role in the perception of the position of the body and its parts in space.

A healthy person determines with absolute certainty the position of his limbs and other parts of the body without checking this position with the aid of vision. This is made possible with the aid of the muscle-joint sensation.

Contractions of the skeletal muscles stimulate the nerve endings situated in the muscles and in the joints. The process of excitation which develops as a result of this stimulation reaches - over the nervous pathways - the cerebral cortex, where the sensation indicating changes in the position of the body arises.

Due to the muscle-jointsensation members of various professions, including the flying personnel, develop a feeling for the amount of strength that should be applied to the control levers during the different movements of the airplane.

The Tactile Analyzer

The function of the tactile, or touch, analyzer, consists in the determination and discrimination of the surface of objects.

The tactile receptors are situated in the skin and are stimulated mechanically by touch and pressure. The process of excitation which arises in consequence proceeds along the nervous pathways into the spinal cord and hence into the cerebral cortex where the corresponding sensation arises.

Analyzers of Heat and Cold

Perception of the temperature of the surrounding medium is based on thermic influences upon special receptors which respond to heat and to cold. Receptors of heat and cold are situated separately in the skin and in the mucous membranes. Stimulation of these nerve endings /37 produces the feeling of warmth or cold. Nervous impulses which proceed from the heat or cold receptors pass through the spinal cord and enter the cerebral cortex where the sensation of warmth or cold in all its nuances arises.

The Gustatory Analyzer

The peripheral part of the gustatory analyzer consists of papillae situated on the surface of the tongue. Chemical compounds dissolved in water are the stimuli of the gustatory papillae.

The excitation which arises in the papillae reaches along the nervous pathways the gustatory center situated in the cerebral cortex.

Man perceives four gustatory sensations: salty, acid, sweet, and bitter tastes, and a multitude of combinations. It must be emphasized that under conditions of oxygen deficiency the capacity to taste sweet tastes decreases and the capacity to taste acid tastes increases.

The Olfactory Analyzer

The olfactory analyzer, the peripheral part of which is situated in the nasal cavity, perceives the smell emitted by various substances.

The olfactory cells, which have an oval body and two long processes, are situated within the mucous membrane in the so-called olfactory area of the nasal cavity. One of these processes serves as receptor for the stimulus, the other constitutes part of the olfactory nerve which proceeds to the brain. During the inspiration, substances suspended in the air enter from the inhaled air through the nose into the olfactory area, where they stimulate the olfactory receptor, thus inducing the formation of nervous impulses which proceed to the olfactory center in the brain.

Respiration

The function of the respiratory organs consists in the performance of gas exchange (mainly oxygen and carbon dioxide) between the atmospheric air and the body. The respiratory organs consist of the respiratory tract and the lungs (Figure 6). The following parts belong to the respiratory tract: the nose, the pharynx, the larynx, the trachea, and the bronchi. The lower end of the trachea (the windpipe) divides into two bronchi which enter the right and left lung respectively. Within the lungs the bronchi branch out repeatedly into fine branches which end in the pulmonary vesicles or alveoli, the diameter of which /38 reaches about 0.2 mm. In other words, the lungs represent a system of very small pulmonary vesicles (alveoli) which are surrounded by a dense network of blood vessels (capillaries) and of bronchi of different diameter.

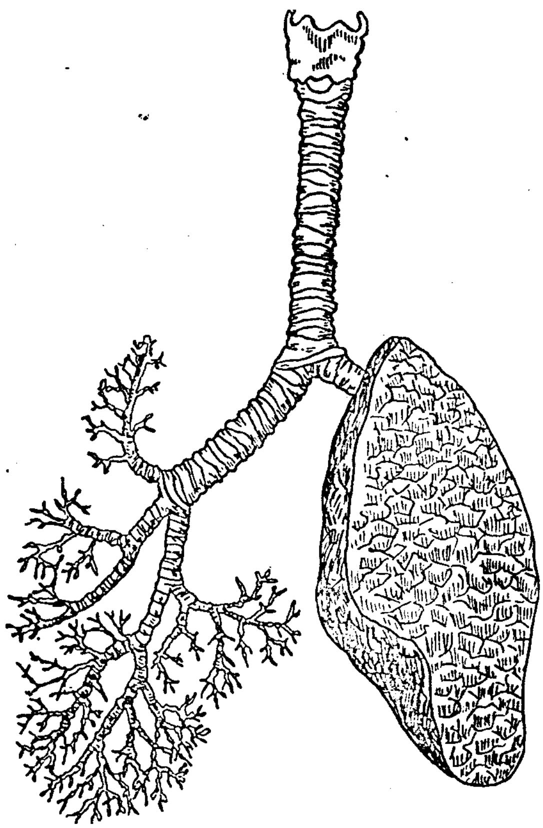
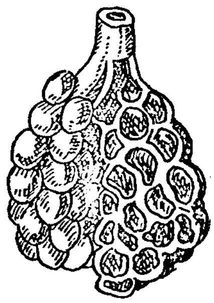


Figure 6. The Human Lungs

The diffusion of oxygen and carbon dioxide takes place in the alveoli (Figure 7).

The lungs contain on the average about 700,000,000 pulmonary vesicles (alveoli) and although their diameter is very small the total surface of the lungs reaches about 90 - 120 m^2. This enormous surface of the lungs facilitates the rapid saturation of the blood with oxygen and the elimination of carbon dioxide from the blood.

The air contained in the lungs is being continuously exchanged. This exchange takes place during inspiration and expiration. During inspiration the volume of the thoracic cavity increases due to the contraction of the intercostal muscles and, consequently, the pressure within the chest decreases. For this reason air will flow through the respiratory tract into the lungs. During expiration the reverse process takes place. /39



The lungs contain 700,000,000 alveoli. $\Phi = 0.2$ mm.

The surface of the pulmonary alveoli = 110 m^2.

Figure 7. The Pulmonary Alveoli

The adult person in a state of rest performs about 16 - 18 respirations per minute. The frequency of respiration increases during physical effort parallel to the degree of the effort.

During normal respiration at rest, man inspires and expires with each inspiration and expiration about 500 cm^3 of air. This volume of air is called tidal air.

After a normal inspiration a man can, by further contraction of the respiratory muscles, inspire an additional volume of air, on the average about 1,500 cm^3. This volume is called complementary air. After a normal expiration a man can expire an average of a further 1,500 cm^3. This volume is called reserve air.

The maximum volume of air which a man can expire after the deepest possible inspiration is called vital capacity of the lungs. The latter consists of the tidal air, the complementary air and the reserve air. In adult persons the vital capacity of the lungs varies over a fairly wide range - between 2,000 and 6,000 cm^3 - sometimes even more.

The vital capacity of the lungs presents one of the most important indexes of physical development, and can be increased by training of the respiratory muscles.

After the deepest possible expiration, the lungs still contain about 1,500 cm^3 of air, which is called residual air. Consequently, the total quantity of air contained in the lungs consists of the sum of the vital capacity and the residual air.

The exchange of gases which takes place continuously in the lungs /40
is called pulmonary ventilation. This reaches, in a state of rest in man, about 6 - 7 liters per minute.

Physical work increases the pulmonary ventilation to a considerable degree, depending on the intensity of the effort. It may also increase to a greater or lesser degree during flights at great height under conditions of decreased partial oxygen pressure if no additional oxygen is supplied through the oxygen apparatus on board the aircraft.

The gas exchange does not take place directly between the gases contained in the blood and the atmospheric air, but between the gases contained in the blood and the alveolar air which latter, with regard to its composition, is quite different from the atmospheric air (Table 5).

Air	Content, in %		
	Oxygen	Carbon dioxide	Nitrogen
Atmospheric air (inspired)	20.93	0.03	78.03
Expired air	16.4	3.08	79.8
Alveolar air	14.5	5.6	79.9

Table 5

During each normal inspiration at rest, only part of the air (about two thirds) enters the alveoli and takes part in the gas exchange; about one third of the air inspired at rest remains in the air passages: the nasal cavity, the oral cavity, the trachea and the bronchi. This portion of the air does not take part in the gas exchange. The space filled with the air which does not take part in the gas exchange is called dead-space air. In the adult, this volume amounts to approximately 140 - 150 cm^3. Given a tidal volume of 500 cm^3, only 360 cm^3 of the atmospheric air reaches the alveolus, and 140 cm^3 remain in the dead-space air. It thus appears that only about 360 cm^3 of the alveolar air (2,500 cm^3) are renewed with each inspiration, that is about one seventh of the volume.

The alveolar air in its turn is also different from the expired air. This is due to the fact that in the beginning of the expiration 140 cm^3 of air are removed from the dead space, in which air the percent of oxygen contained is not different from the atmospheric air, and this is followed by 360 cm^3 of alveolar air. In other words, the expired air represents a mixture of 140 cm^3 atmospheric air and 360 cm^3 alveolar /41
air. For this reason, the expired air contains a higher percent of oxygen than the alveolar air.

The partial pressure of gases in the atmospheric air and the alveolar air respectively is shown in Figure 8.

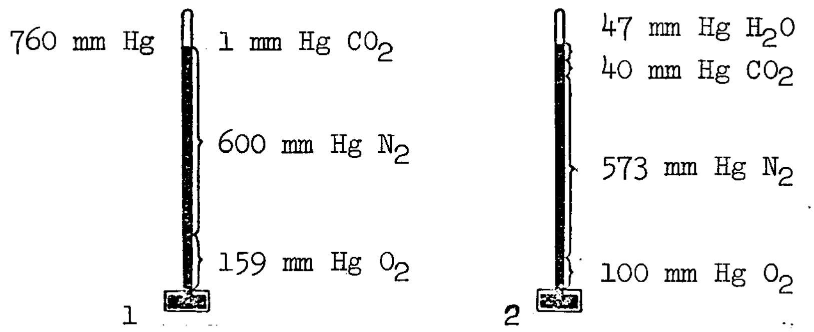
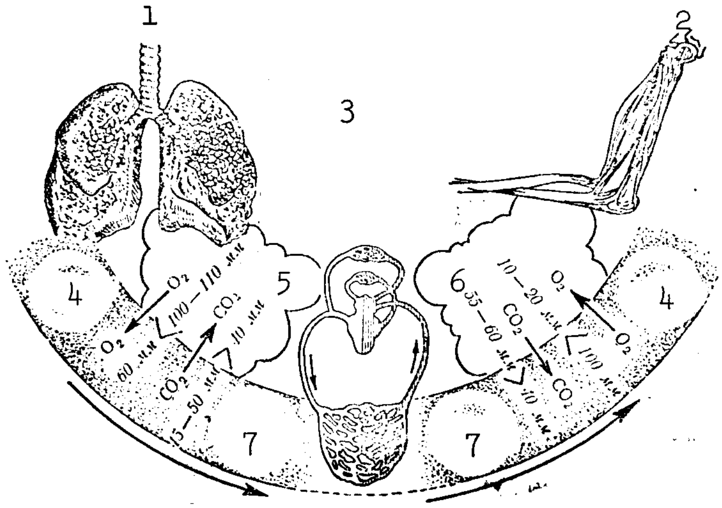


Figure 8. Partial pressure of gases in the atmospheric air and the alveolar air respectively.
1) In dry atmospheric air; 2) in alveolar air ($t = 37^o$)

The gas exchange between the alveolar air and the blood takes place through the alveolar membrane which consists of a single layer of epithelial cells and capillaries. This membrane is extremely thin: its thickness reaches only about 4 μ, a fact which is very favorable for the diffusion of gases (Figure 9).

The transfer of oxygen from the alveolar air into the blood and of carbon dioxide in the reverse direction can be explained by the law of diffusion. According to this law, gas always passes from a space of higher partial pressure into a space in which its partial pressure is lower. The relative pressure of each of the gases contained in the air, on the other hand (e.g. oxygen or carbon dioxide), depends on the atmospheric pressure and the percentile content of the corresponding gas in the air. The partial pressure of oxygen in the alveolar air is considerably higher than its pressure in the venous blood which enters the lungs. For this reason, oxygen passes through the alveolar wall and the capillaries into the blood. /42



MM = mm Hg

Figure 9. Scheme of gas exchange. 1) From the lungs; 2) to the tissues; 3) Oxygen is delivered 4) Hemoglobin; 5) Alveoli; 6) Tissues; 7) Oxyhemoglobin

As far as carbon dioxide is concerned, its content and consequently its pressure in the alveolar air, is considerably lower than in the venous blood which flows through the pulmonary capillaries. For this reason, carbon dioxide passes through the capillary wall and alveolar wall into the air contained in the lungs, and is removed from the lungs together with the air.

The venous blood which supplies carbon dioxide to the lungs becomes oxygenated and turns into arterial blood. It enters the arteries of the systemic circulation and flows through all tissues and cells of the body.

In the tissues oxidative processes take place continuously which lead to the absorption of oxygen and to the excretion of carbon dioxide. The blood flowing through the tissues contains great quantities of oxygen which, following the laws of diffusion, leave the blood through the capillary wall and enter the interstitial fluid. From the latter it enters the tissues; the carbon dioxide, on its part, passes from the tissues into the blood. In this manner the blood passing through the tissues is deprived of part of the oxygen, becomes rich in carbon dioxide and turns into venous blood. The blood then flows through the veins of the systemic circulation into the right half of the heart, and from here into the lungs, where it is turned again into arterial blood.

Blood and Circulation

Blood. The importance of the blood consists in the fact that it supplies nutrient substances and oxygen to the cells; it removes products of metabolism from the cells, which products form as a result of the vital functions of the cells; the blood maintains contact between the organs by transmitting substances produced in different organs; it plays an important part in the defense of the body against bacteria which cause various diseases.

Any marked change in the composition and properties of the blood, due to whatever cause, leads to various disorders in the body.

The quantity of blood in the body reaches on average one-thirteenth of the body weight which, for an adult person of average weight, amounts /43 to about 5 liters. The blood consists of a liquid part (plasma) and formed elements (or cells) of three different types: the erythrocytes (or red cells), the leucocytes (white cells) and the thrombocytes or platelets.

The erythrocytes represent cells without a nucleus, the shape of which resembles biconcave discs of about 8 μ diameter, and about 2 thickness. The lifetime of the red cells has not been established precisely, but is assumed to be equal to 15 - 20 days. According to the available data, about 10 millions of these cells perish in every second.

One mm^3 of an adult person contains 4.5 - 5 million red cells, and in the total mass of human blood there are about 31 billion red cells.

The physiological role of the red cells consists in the fact that they contain hemoglobin. Hemoglobin represents a compound of protein and heme, a special red substance containing iron. Hemoglobin has the capacity to bind oxygen energetically. At the moment when blood passes through the pulmonary capillaries an unstable chemical compound of hemoglobin and oxygen - oxyhemoglobin - is formed.

The erythrocytes adsorb oxygen through their surface. Consequently, the greater the total surface of red cells, the better and the more rapid the process of gas exchange. The small size of the red cells represents an adaptation which secures the rapid saturation of hemoglobin with oxygen.

The human red cells, which are of very small size, have, due to their enormous number, a very large surface. This so-called "respiratory surface" of the red cells secure a rapid gas exchange in the lungs and tissues of the human body.

Blood, saturated with oxygen, is called arterial blood. It supplies oxygen from the lungs into the tissues. The blood which gave off oxygen to the tissues is then called venous blood.

The number of red cells in the human blood may increase or decrease, depending on the physiological state of the body, and also depending on various diseases.

The leucocytes are also cells. Their size varies between 7 and 15 μ . Their number reaches 6,000 - 8,000 in 1 mm^3 blood, and increases in a number of diseases. In some diseases, the number of leucocytes, conversely, decreases.

The leucocytes mainly fulfill a protective function in the body; /44
they ingest micro-organisms entering the body.

The blood platelets, or thrombocytes, are minute cells. The number of thrombocytes in 1 mm^3 blood varies between 250 and 100 thousand. If the continuity of the blood vessels is disrupted, as in the case of hemorrhages, the thrombocytes which are easily destroyed represent the centers from which coagulation of the blood begins.

Circulation. The blood is in a state of continuous movement. Interruption of the movement of blood causes death, as all organs, particularly the brain, are very sensitive to deficiency of oxygen and nutrient substances. The organs of circulation maintain a continuous flow of blood (Figure 10).

The organs of circulation include the heart and the blood vessels. Within the system of blood vessels we discern arteries, veins, and capillaries. The heart represents a hollow organ which mainly consists of muscle tissues. The heart may be compared to a pump, with the aid of which blood is pumped at certain intervals into the arteries and which conveys a certain speed of movement to the blood.

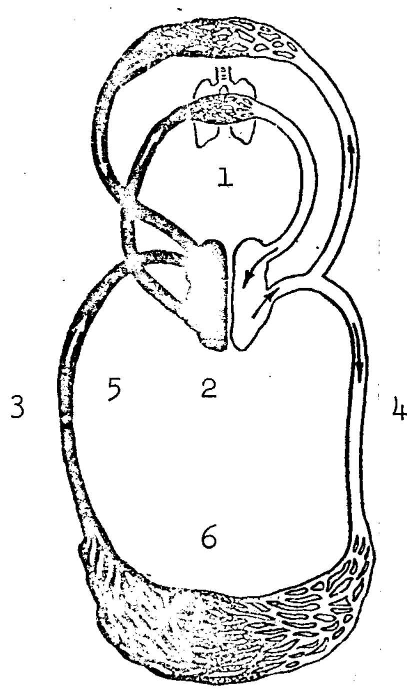


Figure 10. Scheme of Circulation. 1) Pulmonary circulation; 2) Systemic circulation; 3) Venous blood; 4) Arterial blood; 5) 20 cm/sec; 6) 0.08 cm/sec.

The cavity of the heart is divided by a solid membrane into two halves, the right and the left half. Each half consists of two departments communicating with each other: the ventricles and the auricles. In consequence the heart consists of four chambers: the right auricle and the right ventricle, the left auricle and the left ventricle.

Arteries are blood vessels in which blood pumped out from the heart, rich in oxygen and nutrient substances, flows to all organs and tissues. /45

Veins are blood vessels through which blood coming from the organs of the body returns to the heart. This blood is poor in oxygen and nutrient substances.

Capillaries are minute blood vessels which connect small arteries with the small veins. The length of the capillaries reaches 0.5 mm, and their diameter varies between 0.008 and 0.01 mm. Through the capillary wall, which represents a very thin membrane, exchange of substances and gases between blood and the cells of the body takes place.

The Systemic Circulation

During the contraction of the heart muscle, blood from the left ventricle enters the largest arterial blood vessel: the aorta. From here it is distributed through the network of arterial blood vessels to all tissues and organs of the body and, having given off oxygen and nutrient substances to the tissues, returns through the veins into the right auricle. This completes the systemic circulation.

The Pulmonary Circulation

From the right auricle, blood enters the right ventricle, from which it is pumped into the pulmonary artery. The pulmonary artery divides into branches which sub-divide into a multitude of capillaries which form a dense network round the pulmonary alveoli. From the capillaries, small veins begin which unite into larger veins which enter the left auricle. Among all arteries of the body, only in the pulmonary artery is the blood venous instead of arterial. In the pulmonary veins, on the other hand, the blood is of arterial character.

In the lungs, gas exchange between the blood and the external environment takes place through the extremely thin walls of the alveoli and capillaries.

The speed of the blood flow through the blood vessels is maintained at an adequate level by the function of the heart. The heart of an adult person contracts on average 60 - 80 times a minute.

Blood flows at a certain speed through the blood vessels, and in various parts of the circulation system the speed of flow is different. The speed of blood flow is greatest in the aorta, where it reaches 0.5
m per second; in the capillaries the speed of the blood flow reaches /46
0.5 mm, i.e. it is one thousand times lower than in the aorta. (Translator's remark: The original says ten thousand times lower, which is obviously an error since a millimeter is one thousandth of a meter.)

The quantity of blood expelled by the heart in a single beat is called the stroke volume of the heart. In a healthy person the stroke volume constitutes for each of the two ventricles an average of 70 cm^3. The quantity of blood expelled by the heart in a minute is called the minute output of the heart.

At rest, the minute output amounts to about 5 liters for each ventricle. Consequently, the heart expels in the course of an hour about 300 liters of blood and thus carries out an enormous amount of work.

The more intensive the activity of a person, the more intensive the work of the heart. The heart can intensify its work in two ways: by increasing the frequency of heart beats, or by increasing the stroke volume of the heart.

Under different conditions various organs may obtain greater or lesser quantities of blood, even if the activity of the heart remains unchanged. This depends on the intensity of work performed by one or the other organ. In these cases the flow of the blood to one organ will increase at the expense of the flow to other organs.

The Musculo-Skeletal System

In any position the body is supported by bones. This represents the supporting function of the skeleton. The skeleton, which covers cavities occupied by internal organs with its bones, performs a protective function. Finally, the skeletal system together with the muscular system, represents the locomotor apparatus of man. The bones are special levers which are brought into motion by the contraction of the muscles attached to the bones.

The muscles cause movement of the body or of parts of the body. Every active movement of the body is caused by contraction of muscles. Human life is inconceivable without motion.

The skeletal system, which consists of more than 200 bones (Figure 11) is usually divided into the following parts: the skull, the vertebral column, the thorax, the pelvis, and the upper and lower extremities. Each of these parts consists of several bones which are united in a mobile or immobile manner. Each part of the skeletal system performs /47
its own role. For example, the skull protects the brain against external agents (mechanical, thermic, and others); the same role is performed by the vertebral column with regard to the spinal column. The spinal column represents, in addition to its protective role, the main support for the trunk. The vertebral column consists of 33 vertebrae, which are united by cartilages and ligaments. The joints between individual vertebrae permit a certain mobility.

The thorax is formed by ribs, the thoracic part of the vertebral column and the sternum. The links between the bones are to a certain degree mobile, which secures the mobility of the whole thorax and permits respiratory movements. The thorax carries out, in addition to its supporting function, a protective role, protecting the heart and the lungs against external agents.

The pelvis, which consists of several bones, serves as support for the organs of the abdominal cavity and for the lower extremities.

The bones which form the upper and lower extremities represent peculiar levers which are brought into motion with the aid of muscles. All bones are united with the aid of ligaments. Mobile links between bones are called joints. The joints of the upper and lower extremities carry out the most important functions. All movements carried out by man are the result of the work of muscles which are attached in a certain manner to the bones. While carrying out contractions, the muscles carry out mechanical work. The source of energy for the contraction of the muscles consists in the breakdown of complex organic compounds, a breakdown which takes place only in the presence of oxygen.

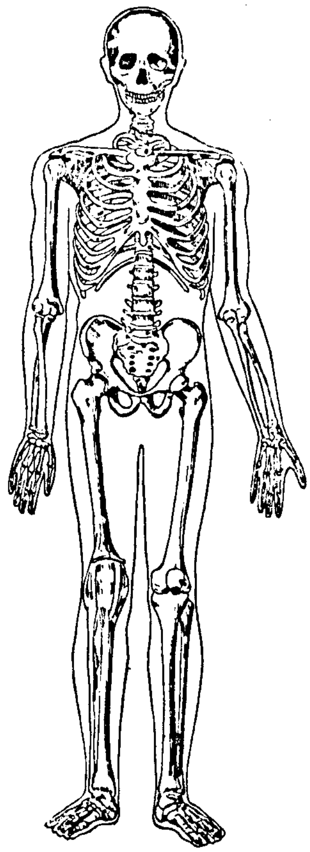


Figure 11. The Human Skeletal System

The oxygen and the organic compounds required by the muscles are supplied by the blood. /48

The stimulus which causes the muscle to act arrives at the muscle along the centrifugal nerves from the central nervous system. The excitation in the central nervous system arises either as a consequence of the stimulation of the endings of centripetal nerves situated in the skin, the muscles, tendons or other organs, or as a result of central impulses during the performance of one or the other complex motor function.

However automatic numerous movements of man may appear, they all begin and end under the control of the cerebral cortex.

The function of the muscles thus depends on the nervous system as well as on the organs of circulation, respiration and excretion.

The Excretory System

The organs of the human excretory system include the kidneys as well as the skin, the lungs and the alimentary tract. The function of the excretory organs consists in the removal from the body of the end products of metabolism no longer required by the body.

The main end products of metabolism in the human body are water, carbon dioxide, salts, urea, and others. Breakdown products of red cells, bile pigments, calcium phosphate which is insoluble in water, and iron, are removed through the intestinal canal. Carbon dioxide and water are removed through the lungs. Breakdown products soluble in water are removed through the kidneys as constituents of the urine and through the sweat glands. The kidneys are the main organs of excretion.

The quantity of urine excreted by a person is different on different days. It will depend on the amount of liquid drunk by the person, the character of the food and the intensity of physical work as well as on the climate. If great quantities of liquid are consumed, the quantity of urine may reach 20 liters per day. At the average, however, the kidneys excrete about 1.5 liters daily which contain up to 60 grams of various salts of organic or inorganic origin.

Any disorder of the renal function may lead to the retention of substances excreted as a result of metabolic processes in the cells in the blood. In these cases the above substances cause intoxication and may cause death.

The skin, which represents the external cover of the body and which /49 defends the organs lying under the skin against mechanical damage and infiltration of various micro-organisms, plays an important part in the excretory processes. While speaking of the excretory function of the skin, one has to discuss above all the role of the sudoriparous or sweat glands. The sweat glands represent long narrow tubes coiled into convolutions, which are situated in the subcutaneous fat layer. At one end the sweat glands open on the surface of the skin. The distribution of the sweat glands over the surface of the skin is uneven. The greatest number of sweat glands is found in the axillary region and inguinal region and on the palms and soles.

In these places 1 cm^2 of skin contains up to 1,000 sweat glands. The function of the sweat glands mainly consists in the maintenance of the amount of water contained in the body at the required level. Water containing the same substances as the urine but in much lesser concentration is removed through the sweat glands.

In the course of a day, the sweat glands remove about 0.4 - 0.6 liters water and about 10 grams of various substances, mainly salts dissolved in the water. This quantity of water is continuously excreted on the surface of the skin, and is invisible to the eye. In the case of intensive muscular effort or high temperature in the surrounding air, however, the excretion of sweat increases considerably and may reach several liters per day.

Sweating plays an important role in the maintenance of the body temperature at a certain level during temperature variations in the surrounding air.

The role of the lungs as an organ of excretion consists in the removal of carbon dioxide, as well as of a certain quantity of water in the shape of vapor, from the body.

In the course of a day, about 600 - 750 grams of carbon dioxide and up to 0.4 liters water are removed from the body through the lungs.

The Digestive System

Day by day, food products containing various quantities of nutrient substances, proteins, fats and carbohydrates enter the alimentary system. In addition, the food products contain mineral salts and vitamins.

The nutrient substances entering the body are used to form new cells /50
and also as source of energy for the vital functions.

The nutrient substances (proteins, fats and carbohydrates) ingested with the food cannot, however, be used by the cells of the body in the form in which they are consumed. They must be adequately transformed, which transformation is carried out by the digestive organs. During the process of digestion, complex organic compounds are broken down into soluble compounds which can easily enter the cells.

The processes which take place in the digestive tract can be divided into two groups: 1) physical and chemical transformation of the food; 2) resorption of the breakdown products which form as a result of the above changes.

The physical changes of the food consist of disintegration and the solution of various constituents.

The chemical changes in the food consist in the breakdown of complex substances into simpler substances. Proteins are broken down to amino-acids, the molecules of which represent constituents of the more complex protein molecules. The fats are broken down into glycerol and fatty acids, and the carbohydrates (sugar, starch and others) to glucose, fructose and galactose.

All these complex changes take place under the participation of the so-called enzymes which shorten many times the time required for the chemical reactions in the body.

Resorption denotes the process in the course of which the end products of the breakdown of nutrient substances enter the blood. The blood transports these substances throughout the body to various organs and tissues where the cells assimilate the substances required.

The undigested residue of the foods enters the large intestine and subsequently the rectum, whence it is removed in the shape of stool which contains about 100 - 150 cm^3 water.

The process of digestion and resorption is accompanied by considerable intensification of the function of all organs of the digestive system. For this reason the process of digestion, like any other active work, leads to an increased consumption of oxygen by the digestive organs. In view of this fact, the blood supply to the digestive organs increases during the period of digestion, while the blood supply to other organs and systems including the central nervous system, decreases during this period. For this reason, consumption of large quantities of food by airmen before a flight should take place at least 1.5 - 2 hours before the start of the flight. This is further important in view /51
of the fact that in the case of oxygen deficiency at great height the digestive organs' activity is suppressed and the processes of digestion are considerably delayed.

Finally, it must be emphasized that the generally recognized founder of our contemporary knowledge concerning digestion was the great Russian physiologist I. P. Pavlov. The investigations of I. P. Pavlov concerning the digestive processes, for which he was awarded the Nobel Prize in 1904, not only created the modern physiology of digestion, but also opened the way for the development of the Pavlovian teaching concerning conditioned reflexes.

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CHAPTER IV

PHYSIOLOGY OF HIGH ALTITUDE FLIGHT /52

High Altitude Sickness and Its Prevention

Modern combat planes are fitted with hermetic cabins and the necessary oxygen apparatus, which during normal flight ensures the required oxygen supply and prevents high altitude sickness. According to existing regulations, Pilot's Handbook of the Air Force, the flying personnel of fighter aircraft must use oxygen apparatus from ground level upwards, the flying personnel of bombers from altitudes of 4,000 m onwards and if the duration of the flight is scheduled to exceed four hours, from 3,000 m onwards. All these measures are aimed at preventing even minimal oxygen starvation of the flying personnel.

However, even if hermetic cabins and oxygen equipment are available and the regulations of the Pilot's Handbook are complied with, cases of high altitude sickness may occur in the case of failures during the flight (e.g. leaks in the cabin at high altitudes), failures in the oxygen equipment or incorrect use of the oxygen equipment on board.

The pilot should know the causes, the nature and the possible consequences of high altitude sickness, as well as the methods and means to prevent its recurrence.

In aviation medicine study of oxygen starvation, which is the basic cause of high altitude sickness, is carried out primarily in chambers with reduced barometric pressure.

Study of the effects on the human body of low barometric pressure /53 was carried out for the first time in connection with high altitude mountain expeditions. The reaction of the human body to the effects of the rarefied mountain air was designated by the term "mountain sickness". Under this term we understand particular manifestation of sickness which develops in the human body during the climbing of high mountains and is characterized by the following basic symptoms: muscular weakness, shortness of breath, headache, dizziness, nausea, nose bleeding.

With the progress in aviation and air travel, the height and the rate of ascent increased rapidly. It was found that when people were carried to high altitudes in air balloons or aircraft a complex of phenomena developed which were reminiscent to a certain degree of high mountain sickness but differed from it by certain features.

Under the influence of low barometric pressure during flight, a number of disturbances occur in the functions of individual organs and in the body as a whole. Thereby, the main factor is not the mechanical effect of the reduced barometric pressure but the reduced partial pressure of the oxygen in the inhaled air.

At normal atmospheric pressure of 760 mm Hg and partial oxygen pressure of 159 mm Hg, the blood in the capillaries of the lungs of healthy people becomes sufficiently saturated with oxygen and thereupon the latter is fed in sufficient quantities to the tissues by means of the blood circulation.

The degree of saturation of the blood with oxygen depends on the partial oxygen pressure in the alveolar air. The higher the partial oxygen pressure in the alveoli; the better and more full will be the process of oxygen saturation with blood and, inversely, if the partial oxygen pressure in the alveoli decreases, there will be a decrease in the intensity of saturation of the blood with oxygen.

The changes in the partial oxygen pressure of the inhaled air and of the alveolar air at various altitudes are given in Table 6.

The partial oxygen pressure in the alveolar air depends on the magnitude of the partial pressure in the atmosphere. Obviously, the higher the partial pressure of the oxygen in the atmosphere, the higher will be the corresponding pressure in the alveolar air and, vice versa, the lower the partial pressure of the oxygen in the atmosphere the lower it will be in the alveolar air.

Altitude, m	Barometric pressure, mm Hg	Partial oxygen pressure, mm Hg	
		Inspired air	Alveolar air
0	760.00	159	103
1000	674.10	141	90
2000	596.10	125	79
3000	525.79	110	69
4000	462.26	98	60
5000	405.00	85	52
6000	353.77	74	44
7000	307.87	64	38
8000	266.86	56	32
9000	230.40	48	26
10000	198.10	41	22
11000	169.69	36	18
12000	144.80	30	14
13000	124.15	26	11
14000	105.60	22	8
15000	90.10	18	6

Table 6

As the altitude increases the overall barometric pressure decreases and parallel with it the partial oxygen pressure in the atmosphere will decrease as well as the magnitude of the partial oxygen pressure in the alveolar air.

Under conditions of reduced partial oxygen pressure in the atmosphere, there will be a decrease in the oxygen saturation in the blood. Furthermore, if the partial oxygen pressure decreases, the affinity of hemoglobin for oxygen (the ability of hemoglobin to react with the oxygen) decreases. If at sea level the oxygen saturation of the blood is almost 100%, at an altitude of 3,000 m the saturation will be 90%; at an altitude of 4,000 m it will be 85%; at 5,000 m it will be 75 - 80%; and at 6,000 m it will be 70 - 75%.

If the percentage of saturation of blood with oxygen decreases, there will be a disturbance in the normal oxygen supply to the tissues resulting in oxygen starvation of the tissues.

The degree of manifestation of the oxygen starvation depends on the altitude, duration of stay at the altitude, the state of the body of the pilot at the time of rising to this altitude, and on his individual reaction. It should be noted that for older and sick people, oxygen starvation sets in at lower altitudes than for young and healthy people.

Symptoms of High Altitude Sickness /55

If no oxygen apparatus is used, the first symptoms of high altitude sickness may occur even at an altitude of 2,500-3,000 m. At an altitude of 4,500-5,000 m these symptoms become sufficiently obvious in most people; at altitudes of 5,500-6,000 m they may become dangerous, and at altitudes of 7,000-7,500 m serious disturbances develop including loss of consciousness.

Experience shows that "ascents" in decompression chambers and flights in aircraft at altitudes of 5,000 m and more without additional oxygen supply will very rapidly bring about the appearance of characteristic symptoms of high altitude sickness: the sensation of burning in the face, rush of blood to the head, headache, reduced working ability, lowered perception, lowered efficiency in computing operations, impairment of fine co-ordinated movements (Figure 12), slowing-down of reflex reactions to external stimuli, sluggishness, weakness, sleepiness, in some cases a sensation of cold in the extremities, paleness of the skin, perspiration, giddiness, nausea and sometimes vomiting.

The manifestations of high altitude sickness are very varied and occur in various combinations of symptoms in different people and even in the same person at different times. Undoubtedly an important role is played by the degree of oxygen starvation. /56

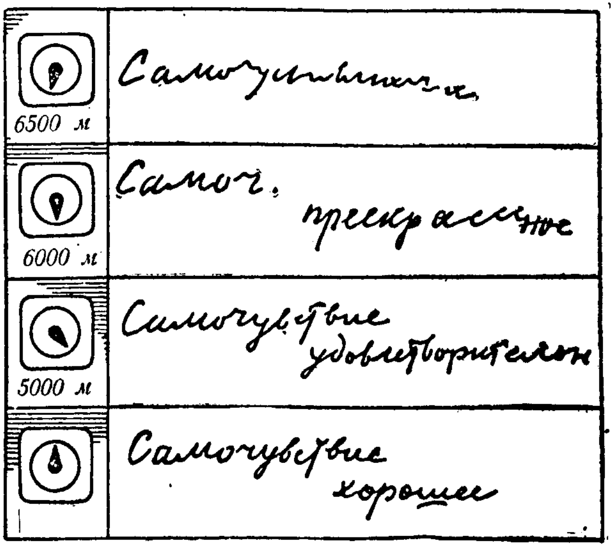

Figure 12. Changes in Handwriting with Altitude. 6,500 m - Feeling ...; 6,000 m - Feeling magnificent; 5,000 m - Feeling well; Ground level - Feeling fine.

The main danger of high altitude sickness consists in the fact that the normal psychic processes are impaired. A man is no longer healthy enough to be able to make a critical evaluation of his own state or to judge his surroundings. Therefore, an unnoticeable transition may take place from light degrees of high altitude sickness to more serious ones. In some cases serious symptoms of high altitude sickness, including loss of consciousness, may occur suddenly although the person feels completely well immediately beforehand.

All the investigations carried out during ascents in balloons, in decompression chambers and also aboard aircraft, indicate that changes which are observed in the body occur primarily in the central nervous system, which is the most highly differentiated system and is the most sensitive to oxygen starvation.

From the various sections of the central nervous system, the most sensitive to lack of oxygen is the cortex of the greater cerebral hemispheres. This is confirmed by the change in the well-being of the person, his behavior, the impairment of the psychic processes and the lowering of working capacity.

Study of the influence of an inadequate oxygen supply on the central nervous system permits distinguishing two phases: stimulation - slight degrees of oxygen starvation have a stimulating effect; and depression -

considerable degrees of oxygen starvation have a depressing effect (they brake the functioning of the cerebral cortex and of the sub-cortical centers).

The stimulation phase usually occurs at an altitude of 2,500-3,500 m and is characterized by increased vitality, an increased interest in the surroundings, a sharpened perception and even an acceleration of psychic reactions.

The depression phase begins at an altitude of 4,000 m. It is characterized by a reduction in the working ability of the person. In this phase the following can be observed: the predominance of the feeling of depression, an impaired capacity for judgment, a drop in the volume of perception, a drop in observational capacity, weakening of the memory, difficulty in observing instruments, reduced ability to carry out simple mathematical calculations, and impairment of the ability to estimate distances. In this phase the pilot may commit numerous errors. In the further state the position can become even worse by the appearance /57 of sluggishness, weakness, apathy and sleepiness.

If the degree of oxygen starvation does not increase (flight at a constant altitude), wavy changes with short periods of stimulation and long periods of depression occur. In this respect it is very characteristic of the impaired judgment of the pilot, under conditions of inadequate oxygen in the inspired high-altitude air, that he believes himself to be completely normal and that his actions are correct. Under these conditions pilots tend to over-estimate their capabilities and the correctness of their actions.

During periods of depression, loss of consciousness may set in. It was found that sudden loss of consciousness occurred only in the case of a very rapid ascent above 5,000 m or in the case of sudden stoppage of the oxygen supply at a high altitude. In most cases man undergoes all the phases: the phase of stimulation, the phase of alternating periods of clear and blurred thinking, and phases of strong depression during which a loss of consciousness may occur. However, in some cases the loss of consciousness may occur suddenly. It is characteristic that the pilot does not remember the onset of the coma and the subsequent states.

Effect of Oxygen Starvation on the Functioning of the Analyzers

As was mentioned earlier, I. P. Pavlov referred to the cerebral cortex as a complex analyzer since in the cortex nerve stimuli from the sensing organs are transformed into perception. In other words, in these centers an image is formed of the objects and phenomena which surround us. Therefore, it is understandable that impairment in the functioning of the cerebral cortex at high altitudes manifests itself relatively quickly in the functioning of the analyzers.

The visual analyzer is highly sensitive to oxygen starvation. Even at 2,000-3,000 m above sea level the reduction in the light sensitivity of the eye is appreciable and at an altitude of 4,500 -5,000 m it is very pronounced, particularly in persons who are not accustomed to high altitudes, or during intensive physical exertion.

Color perception is almost always disturbed with altitude. The first symptoms of disturbance are observed at altitudes between 2,000 and 3,000 m, while the disturbance in color perception is highly pronounced at altitudes between 5,000 and 6,000 m. At these altitudes white is seen as yellowish-gray, and black as gray. Particularly pronounced is the decrease in sensitivity to green and gray colors. At altitudes of 6,000 m and more, the ability to distinguish between gray and green is substantially lost. The sensitivity to red light is less impaired. In order to be able to distinguish other colors, these have to be more saturated than at ground level. /58

Acuity of vision changes very little at altitudes of 4,500-5,000 m, provided the objects are sufficiently illuminated. However, if the illumination intensity is low, the acuity of vision is reduced. This will be the more pronounced, the higher the degree of oxygen starvation or the lower the intensity of illumination of the objects. In daylight, pronounced deterioration in vision acuity is observed at an altitude of 6,000 m.

The field of vision narrows at high altitudes. The first phenomena of narrowing of the field of vision are observed at 4,500 m, and at 6,000 m the narrowing of the field of vision is highly pronounced.

The perception of depth at high altitudes is also impaired. In 30% of subjects investigated, this impairment was observed at an altitude of 3,000 m. It was more pronounced at 5,000 m and was observed in approximately 55% of the persons tested, while at 6,000 m it was observed in 100% of the subjects.

The impairment of the depth perception at high altitudes is due to the impairment of the muscle balance of the eye muscles resulting from oxygen starvation.

In conclusion it is pointed out that the time of perception of visual impressions is longer at high altitudes, as a result of which some pictures, events and processes which are impressed on the retina during a short period will not be perceived. These phenomena may occur at altitudes over 5,500 m, if atmospheric air without additional oxygen supply is used for breathing.

A change in the function of the audio analyzer at high altitudes is less pronounced than that of the visual analyzer. Hearing at high altitudes does not suffer any important changes. Experimental data of the acuteness of hearing have shown that only at altitudes above 6,000 m will there be a tendency to a reduction in the acuteness of hearing, and then only if the additional oxygen supply is not used.

According to the opinion of the investigators, reduced hearing at high altitudes is due to the impairment of the functioning of the cerebral cortex. /59

Vestibular analyzer. Change in the function of the vestibular analyzer is observed only in the case of serious oxygen starvation. Experiments involving rocking the subject have revealed that for some persons impairment of the vestibular system occurred in the case of oxygen starvation, although no such impairment was observed in the same subjects upon administering normal atmospheric air.

The greater cerebral cortex is the highest regulating and co-ordinating organ of all the vital functions of the body. Impairment of the normal functioning of the cortex reflects itself quickly on the functions of the underlying sections of the brain as well as on the functioning of the internal organs. The impulses from the cerebral cortex control and correct the progress of a great variety of processes in the body, including processes inside individual cells. In addition, any change in the state of the internal organs is signaled into the central nervous system by means of impulses.

Impairment of the functioning of the cerebral cortex under conditions of oxygen starvation may reflect on the work of internal organs and a change in their functioning may in turn influence the functioning of the cortex.

Due to the regulating activity of the cerebral cortex during moderate degrees of oxygen starvation, an intensification is observed in the respiration and the blood circulation. As a result, the lack of oxygen starvation becomes more pronounced, an impairment in the functioning of the respiratory and blood circulation organs is observed.

Respiration Reaction at High Altitudes

Numerous experimental data show that the respiration function is most sensitive to a reduction of partial oxygen pressure in the inspired air, which is linked with a drop in the overall barometric pressure.

A constant characteristic breathing reaction to the inadequate oxygen supply manifests itself in the intensification of respiration, which brings about increased ventilation of the lungs. Increased lung ventilation at high altitudes manifests itself by an increased rhythm and depth of respiration; thereby most of the lung alveoli which do not normally participate in breathing will be drawn into this activity. /60

A slight increase in lung ventilation is perceptible even at an altitude of 1,000 m, while at an altitude of 2,500 m it manifests itself quite clearly.

The degree of increased lung ventilation differs from one individual to another. In some cases it may increase by 100%. Generally, however, the increase when at rest depends on altitude and rate of ascent. The higher the altitude and the rate of ascent or the drop in the partial oxygen pressure (for instance when the oxygen equipment fails at high altitude), the greater will be the increase of lung ventilation. Lung ventilation at high altitudes increases particularly steeply with physical exertion, since any such exertion increases the oxygen requirement of the body.

An increase of the lung ventilation at high altitude is a compensating reaction of the body to an inadequate supply of oxygen and leads to an increase in the partial pressure of the oxygen in the alveolar air and, consequently, increases the saturation of blood with oxygen. The latter is by far the most important and beneficial effect of the increased ventilation of the lungs. However, an increased lung ventilation may also have a negative effect; namely, in the case of intensified ventilation of the lung an excessive "washing away" of carbon dioxide occurs. Carbon dioxide has a stimulating effect on the respiratory center and plays an important role in the process of saturating the blood with oxygen in the lungs and the transfer of the oxygen from the blood into the tissues of the body.

Within 1 - 2 minutes of breathing with oxygen when at high altitude, normal lung ventilation is restored.

Acute oxygen starvation leads eventually to disorders of the respiratory functions. The respiration becomes uneven, accelerated and shallow; the lung ventilation drops sharply which is a systom of approaching asphyxiation and loss of consciousness. However, the subject may lose consciousness even without a feeling of asphyxiation. A similar disorder of respiration during acute oxygen starvation will occur as a result of exerting pressure on the respiratory center.

Reaction of Blood Circulation at High Altitudes /61

Study of the influence of altitude on the blood circulation organs shows conclusively that the main factor which causes changes in the state of the blood circulation is the decrease with altitude of the partial oxygen pressure of the inspired air.

Experiments in pressure chambers and also during high altitude flights show that if the partial oxygen pressure in the alveolar air is increased to the ground level value (105 mm Hg) by topping with oxygen, the blood circulation organs will not show any reaction which is characteristic of the body at high altitudes without additional oxygen supply. Conversely, these reactions manifest themselves very clearly even under normal atmospheric pressure if gas mixtures are inspired containing a lower proportion of oxygen than the atmosphere at sea level.

One of the earliest and clearest symptoms heralding the change in the functioning of the circulatory system under conditions of inadequate oxygen supply is the change (in most cases an increase) in the pulse rate. This is the best biological index of the reactions of the circulatory system to altitude. In some people the acceleration of the pulse rate starts at an altitude of 600-900 m. Usually the increase in pulse rate will be the more pronounced the higher the altitude; however, there are considerable individual differences.

During prolonged stay at moderate altitudes, it can be observed that the body becomes acclimatized to the given conditions. However, in spite of the fact that the pulse will become a bit slower, it will still be faster than at ground level. Particularly noticeable is the acceleration of the pulse during physical exertions at high altitudes, which is due to the larger oxygen requirements of the body.

The arterial blood pressure at high altitudes in the case of oxygen starvation changes only insignificantly, but in most cases it will increase somewhat. As a result of the speeding up of the heart contractions, the blood will circulate faster and in this way the tissues will receive more oxygen.

In addition to the increased pulse rate and blood pressure, the heart volume per minute also increases, i.e. the quantity of blood pumped into the blood vessels per minute increases. The supply of oxygen to the tissues will be the better, the more blood that flows through the /62
tissue capillaries per unit of time.

With the participation of the nerve-reflex mechanisms the mass of the circulating blood increases; consequently the quantity of red corpuscles (erythrocytes) increases in some cases to 8 million per 1 mm^3, as a result of passage into the blood vessels of the blood deposited in the spleen, liver and skin. This increases the total available breathing surface of the erythrocytes and hence the quantity of hemoglobin, which is the carrier of oxygen. In those cases of oxygen starvation when there is a dangerous drop of the oxygen pressure in the blood vessels of the brain, there is a redistribution of the blood by reflex action, as a result of which the blood supply of the organs which are most important to life - the central nervous system, the heart and the lungs, improves at the expense of a reduced blood supply to the muscles, skin and other organs which have a higher resistance to inadequate oxygen supply.

Thus it can be seen that in the case of inadequate oxygen supply, the organs of the circulatory system bring about a number of reactions which are directed towards ensuring the required oxygen supply to the body.

However, the described changes of the activity of the heart are characteristic of moderate degrees of oxygen starvation. In the case of acute oxygen starvation at high altitudes (6,000-7,000 m), the reserve power of the blood circulation system rapidly becomes exhausted. The pulse either accelerates excessively or becomes very slow, and then the rhythm becomes irregular. Such phenomena precede the state of fainting. It is pointed out that the resistance of the body to an inadequate oxygen supply is greatly reduced by: inadequate sleep prior to flight, over-tiredness, sickness, consumption of alcohol, excessive smoking, sexual excesses, flight on an empty stomach, hardships etc.

The state of blood circulation is influenced also by cold. Under the influence of low temperatures, the metabolism increases and this requires additional oxygen. This imposes additional requirements on the blood circulation and central nervous systems.

In conclusion, to give an overall picture of the influence of inadequate oxygen in high altitude flights on the human body, it is necessary at least sketchily to group the multitude of disorders of the physiological functions of the individual organs and systems into a single entity and to present them in a general form. /63

For the purpose of clarity let us assume the ascent under conditions such that the body has only to contend with the effects of inadequate oxygen supply, all other adverse effects of flight being excluded (Figure 13). The general picture of the phenomena developing at various altitudes will be approximately as follows.

In the lower strata of the atmosphere up to 2,000 m above sea level, there are changes in the well-being of the pilot. This zone is referred to as the indifferent zone. Further ascent is accompanied by changes in the well-being of the pilot. Therefore, the altitude of 2,000 m can be referred to as the reaction threshold. From the altitude of 2,000 m the body begins to compensate the deficiency of oxygen in the air by accelerating the functioning of the blood circulation system and respiration. Due to these compensating reactions of respiration and blood circulation, the body will compensate satisfactorily the inadequacy of oxygen in the inspired air up to altitudes of 3,000 m and the ability of the pilot will not suffer. Therefore, the altitudes between 2,000 and 3,000 m are referred to as the zones of full compensation.

However, it is pointed out that prolonged flights (over 4 - 5 hours) /64
at this altitude will be accompanied by an appreciable drop in working ability.

Figure 13. Zones of Endurance of Altitude. Altitude in km; 9; 8 - Threshold of death; 7 - Critical zone; 6 - Critical threshold; 5 - Zone of incomplete compensation; 4 - Threshold of disorders; 3 - Zone of full compensation; 2 - Threshold of reactions; 1 - Indifferent zone; 0.

If the ascent is continued without additional oxygen supply, high altitude sickness will increase continuously with the passage of time. The reserve mechanisms of the body will no longer be able to compensate fully the inadequate supply of oxygen in the inspired air and ensure the oxygen requirements of the body. The above described changes in the activity of the cerebral cortex, respiratory organs and blood circulation, will begin to manifest themselves and the working ability of the body will decrease, etc. These phenomena can be most frequently observed at an altitude of about 4,000 m. This altitude is referred to as the threshold of derangements and, for that reason, flights at altitudes above 4,000 m without oxygen apparatus are forbidden by the flying regulations.

From an altitude of 4,000 m onwards, begins the zone of incomplete compensation; with further increase in altitude the oxygen starvation becomes more and more pronounced, the phenomena of altitude sickness increase rapidly and disorders of bodily functions become accentuated. The altitude of 6,000 m is considered as the critical threshold, beyond which the so-called critical zone begins. Ascent into this zone without additional oxygen supply becomes dangerous to life. For a relatively short time the pilot may lose consciousness and will recover from this state only after descent to a lower altitude or after being supplied with oxygen.

Of still greater danger is an ascent to 8,000 m and above without additional oxygen supply. At these altitudes the impairment of the working capacity and loss of consciousness may occur very rapidly. In the case of prolonged effects on the human body of such a rarefied atmosphere, there is a danger of serious disorders in the body which may endanger life.

Undoubtedly the above picture is somewhat arbitrary. It is calculated for a certain rate of ascent (1,000 m in 3 min). In the case of a more rapid ascent the picture may change considerably. Furthermore, this picture does not take into consideration variations in the ability of different persons to adapt themselves to the changes of external environments.

Individual capabilities of adaptation to inadequate oxygen supply and, consequently, the individual resistance to altitude reaction of various /65 people is clearly apparent at altitudes between 5,000 and 7,000 m. In the case of ascent to 8,000 m, the individual differences in resistance to altitude are obliterated and at altitudes of 10,000-12,000 m high-altitude sickness develops within approximately the same length of time in all healthy people.

As was mentioned earlier, ascent to altitudes above 6,000 m without additional oxygen supply brings about a danger of deep derangement in the body including complete impairment of the working ability and loss of consciousness.

The time from the beginning of intense oxygen starvation to the onset of acute derangements, which impair fully the working ability and lead to unconsciousness, is referred to as the reserve time. Its duration shortens with increasing altitude (Table 7).

The duration of the reserve time depends basically on the altitude and rate of ascent and intensity of oxygen starvation; it also depends on individual features of the body. Usually, in physically fit persons and persons having an adequate flying training, the reserve time will be somewhat greater than in physically weak persons and those with little flying training.

Altitude, m	Time
	On breathing atmospheric air
7000	4 min
8000	2 min
9000	1 min
10000	40 sec
11000	35 sec
12000	25 sec
13000	65 sec
14000	47 sec
14000	30 sec
	On breathing pure oxygen
15000	19 sec
15000	17 sec
16000	15 sec

Table 7

Reserve Time for Man

Prophylaxis

In order to prevent the unfavorable effects of high altitude sickness in aviation, a set of complex measures is taken which ensures the safety of flying and sustains the working capabilities of the crew. /66

The most effective means of preventing high altitude sickness and ensuring normal life functions and working capability of crews flying at high altitudes is to breathe oxygen provided by oxygen apparatus.

Since on ascent the shortage of oxygen begins to be felt at altitudes over 3,000 m, it is necessary from this altitude onwards to maintain the partial pressure of oxygen in the alveolar air within the physiologically specified limits by using oxygen apparatus which automatically doses the rate of oxygen administration to the mask of the wearer in a quantity which is required for normal breathing at the given altitude.

When the oxygen apparatus is switched on after prolonged oxygen starvation the so-called "paradox effects" can be observed, namely a short-duration decrease of well-being. In cases of prolonged flight, oxygen apparatus should be switched on at altitudes of 2,500 m onwards.

During night flights oxygen apparatus is usually used from ground level onwards, since with low illumination the functioning of the eye weakens considerably, even in the case of insignificant degrees of oxygen shortage.

Flying at altitudes in excess of 12,000 m above sea level, the ordinary oxygen instrument of the "automatic lung" type is no longer able to eliminate the oxygen starvation phenomena. Even at an altitude of 11,000 to 12,000 m the first symptoms of impairment of vision and some of the psychic functions will be noticeable if the lung-type oxygen apparatus is used. At altitudes over 12,000 m, high-altitude sickness sets in and its symptoms will increase much more intensively than during ascent to an altitude above 4,000 m without any oxygen apparatus.

This is due to the fact that at altitudes which exceed 12,000 m, due to the low barometric pressure, ordinary oxygen apparatus of the "automatic-lung" type will no longer be able to ensure the partial oxygen pressure in the alveolar air which is required for normal life, even if /67 pure oxygen is used; this is due to the increase of the specific value of the water vapor tension and the pressure of the carbon dioxide in the alveolar air.

This point is explained by the following theoretical calculation: the fraction of the water vapor tension in the alveolar air is 47 mm Hg, that of carbon dioxide is about 40 mm Hg. Furthermore, the medical oxygen used in aviation always contains about 2% nitrogen, which amounts to 5 mm Hg. Therefore, the sum of the partial pressures of the water vapor, the carbon dioxide and the nitrogen will equal 47 mm Hg + 40 mm Hg + 5 mm Hg; i.e. a total of 92 mm Hg.

If ordinary oxygen apparatus is used, the oxygen is fed into the lungs at a pressure equal to the pressure of the ambient atmosphere.

Consequently, the partial oxygen pressure in the alveolar air will equal the difference between the barometric pressure at a given altitude and 92, i.e. the sum of the pressures of the water vapor, carbon dioxide in the alveolar air and the nitrogen, viz:

$$B - PS = P_{O_2} \text{ alveolar air.}$$

For instance, at an altitude of 13,000 m, where the atmospheric pressure equals 124 mm Hg, the partial oxygen pressure in the alveolar air breathing pure oxygen will, according to the given calculation, equal:

$$P_{O_2} = 124 - 92 = 32 \text{ mm Hg,}$$

and at an altitude of 14,000 m, where the barometric pressure of the atmosphere is 105 mm Hg

$$P_{O_2} = 105 - 92 = 13 \text{ mm Hg}.$$

Thus, the partial oxygen pressure in these cases will be somewhat higher than the calculated values (Table 8). This is explained by the fact that on reducing the partial oxygen pressure in the alveolar air, as well as during flights at low altitudes without oxygen by compensating the increased lung ventilation, partial oxygen pressure of the alveolar air will be maintained at higher values due to the intensified scavenging of the CO_2 from the lungs and the consequent reduction of its partial pressure, as well as the reduction of the water vapor tension.

| Altitude, m | Barometric pressure, mm Hg | Partial oxygen pressure in the alveolar air, mm Hg | | /68
|---|---|---|---|
| | | Calculated | Corrected to allow for the lung ventilation |
| 10000 | 198 | 106 | 106 |
| 11000 | 169 | 78 | 80 |
| 12000 | 145 | 53 | 60 |
| 13000 | 124 | 32 | 42 |
| 14000 | 105 | 13 | 32 |
| 15000 | 90 | 0 | 10-15 |

Table 8

At altitudes in excess of 12,000 m, the supply of oxygen to the body becomes inadequate even if pure oxygen is inspired by means of the "automatic-lung" oxygen apparatus. As a result, high-altitude sickness develops very rapidly and after a short time the following occur: full impairment of working capability and loss of consciousness. Consequently, safe flying with such apparatus is limited to an altitude of 12,000 m.

In this way, using the customary oxygen instruments simulating the automatic lung action in non-pressurized cabins at altitudes in excess of 12,000 m, the pilot may protect his working capability only for a very limited time. The time within which in these conditions a human being retains consciousness is extremely short. Therefore, one should never consider that in this period he could undertake sufficiently active measures to save himself by means of a seat ejector or by descending to a safe altitude. Starting with this assumption, we should consider

the earlier recommendations as unacceptable and consider this time as a factor which has a very important meaning in the flight analysis, in which either the pilot has sufficient means to repair his oxygen equipment, lower himself to a safe height, or by other methods find ways of getting out of the situation in which he finds himself. The high altitude danger from the point of view of a human being may be represented with the help of tests carried out on animals (dogs), according to which the length of their life span at 18,000-20,000 m and above does not exceed 3 minutes. Individual differences in the period of survival occur at altitudes of 13,000 to 15,000 m, but lose their meaning at 16,000 to 20,000 m and above, and the life span of all the animals of /69
this type appears to be practically the same. The main reason for the quick death of the animals under these conditions is the rapidly increasing fall of oxygen pressure in the blood. The increased rate of acute oxygen starvation (anoxia) is explained not only by the sharp fall of the partial pressure of oxygen in the ambient atmosphere, but also by the phenomenon characteristic at these altitudes, namely the degasification of the blood ("degasification of the organism"). With the high degree of the atmosphere rarefaction, according to the laws of diffusion, the body loses from its blood through the lungs the oxygen, nitrogen and carbon dioxide. In the case of depressurization of the cabin, when oxygen apparatus of the "automatic lung" type is used, the degasification process may be expected to occur at altitudes at which the partial pressure of oxygen in the alveolar air is close to zero. These will be the altitudes of 16,500 to 17,500 m and above. In that zone, the breathing with oxygen supplied without excess pressure becomes completely ineffective and the time of retaining consciousness for all people becomes the same, viz. it does not exceed 5-7 seconds and, therefore, it loses its meaning in the flying practice as a "reserve time". This fact points to the great danger which a human being will experience at high altitudes in the absence of the necessary oxygen supply and this should always be remembered by the pilots and technical crews, and means to protect flight crews at such altitudes should be sought.

Contemporary aviation has two means of protection against anoxia: the use of high altitude scaphanders and apparatus for inspiring oxygen under excess pressure.

A modern high altitude scaphander protects the pilot from the action of the rarefied atmosphere at high altitudes, from the acute anoxia and the action of low temperatures, and also lessens the danger of the effects of high and quick pressure drops. However, the scaphander has also a number of intrinsic deficiencies which limit its applicability in the field of aviation. This state of affairs stimulated the development and the introduction into flying practice of an alternative method of securing safe flight at high altitudes - the use of apparatus which supplies oxygen under excess pressure. This apparatus acts in a pressurized cabin as ordinary apparatus of the "automatic lung" type. In the case of depressurization at altitudes in excess of 12,000 m, an automatic switching on of the oxygen supply takes place and for 2 - 3 seconds the excess pressure is allowed to act under the mask. The value of the excess pressure is regulated according to the altitude. /70

Standards were developed so that the excess pressures are normalized in practice. The first region lies within the range of 25 mm Hg and this is recommended at altitudes up to 15,000 m; the second in the range of 65 mm Hg which applies to 18,000 m; and the third in the range of 100 mm Hg which applies to altitudes in excess of 18,000 m. In the case of the first range, only one mask is used, together with the apparatus which secures the supply of excess pressure to the lungs with the oxygen pressure up to 25 - 30 mm Hg. In the second range a mask and an altitude-compensating suit are used which provides counter pressure on the surface of the trunk and the extremities. In the third range of altitude helmet and a mask are used together with the compensating suit.

In these pressure regimes similar conditions are experienced as in breathing with oxygen without the excess pressure, corresponding to altitudes of 13,200, 12,500 and 12,000 m. At altitudes in excess of 18,000 m with the increasing excess pressure under the mask, pain in the region of the face, eyes and neck is felt, which is due to the absence of the compensating pressure in these regions. Absence of compensating pressure in the region of the head and neck leads to a retentive phenomenon, the result of which is that the pressure of blood in the veins of these regions rapidly rises and the walls of the veins stretch, which is the cause of a number of pathological phenomena.

The sensations of pain associated with the use of a mask and the absence of compensating counter pressures in the region of the head and neck may be eliminated by using transparent hermetic helmets covering the whole of the head and neck. This allows further increase of the excess pressure of oxygen in the respiratory system and also a considerable increase in the performance of the aggregate oxygen apparatus as a means of saving flying crews at high altitudes, and also as a means of securing the possibility of continuing flights at high altitudes when the pressurization of the cabin has broken down.

Testing of the new aggregate oxygen equipment comprising the oxygen apparatus, helmet and compensating suit showed that in the third range of the excess pressure (which may total together with the atmospheric pressure 145 mm Hg) this equipment may be exposed to an extremely rarefied atmosphere and yet fully protect the working capability for a long period of time. At the same time, in order to provide the body with oxygen, conditions are created which correspond to the conditions of breathing with oxygen at an altitude of 12,000 m without excess /71 pressure. In this way the above aggregate oxygen equipment is similar to a scaphander in respect of efficiency of oxygen supply.

However, there are substantial differences between the aggregate oxygen equipment and the scaphander. The main difference is in the means of providing the counter pressure to the human body. In a scaphander, air is used for this purpose, but in a high altitude suit mechanical forces of pressure developed by the suit itself are used. In view of its physical properties, the air used in the scaphander allows the same amount of pressure to be applied at all points of the body and, consequently, presents an ideal way of compensating the excess oxygen pressure supplied to the lungs.

Compensation (i.e. counter pressure carried out by means of tension devices of the high altitude suit, is unevenly distributed on the surface of the body. In such places as the armpits and the regions of the groin, the perineum regions and between the shoulder blades, etc., the counter pressure is often much less than in other parts of the body. At altitudes in excess of 19,000 m, in those places retentive phenomena may occur which may lead to a sensation of pain. The uneven distribution of counter pressure along the surface of the body is largely due to the deficiencies of the compensating suit.

The further development of aviation necessitated improvement of the existing altitude suits and development of suits with new, more efficient systems of counter pressure.

Within the undertakings of high altitude sickness prophylaxis and the need of the body to withstand the lack of oxygen, enter also the systematic summer training and stationing in high altitude camps, intensive physical training, suitable conditions of work and living, respiration, rational diet, etc.

The Effect of Falls of Barometric Pressure on the Human Body /72

Under the term "fall of pressure" should be understood a steady or fast change in barometric pressure of the ambient medium. The changes of atmospheric pressure leading to the increase of the pressure are known as compressive falls, and those towards the decreasing pressure as decompressive falls. Subsequently, with rise to an altitude or with the decompression of a cabin of the aircraft, the human body is subjected to decompressive falls, and on descent to compressive falls.

The most important from the point of view of contemporary aviation are the decompressive falls of pressure, the action of which leads to a number of disturbances in the human body which are known under the generic name of decompressive disorders.

Decompressive Disorders

Over a long period of time, the effect of lowered barometric pressure is felt on the human body only as far as oxygen starvation is concerned.

There is no doubt that the leading factor causing the fundamental changes in the body at high altitudes is the oxygen starvation which is assisted by the lowering of the partial pressure of oxygen in the expired air, which is associated with the lowering of the general barometric pressure. However, in contemporary high altitude aviation at heights in excess of 8,000 m, man encounters new difficulties. It appears that at these heights the effect of the decompression itself, i.e. the considerable lowering of the barometric pressure, leads to the development of the so-called decompressive disorders, which appear to be completely different from the well known oxygen starvation phenomena.

It is true, however, that due to the use of pressurized cabins with pressure values not less than 268 mm Hg (which corresponds to 8,000 m in the atmosphere), the possibility of developing decompressive disorders is practically eliminated. However, we may meet with the appearance of decompressive disorders in the case of decompression of a cabin at altitudes in excess of 8,000 m. In addition, decompressive disorders may be observed in experiments with pressure chambers.

In the first stages of the development of aviation, while the flying /73
ceiling was relatively low, decompressive disorders were not observed in aviational practice. These disorders were met only when the flying ceiling exceeded 8,000 m.

Symptoms of Decompressive Disorders

The most characteristic symptoms of decompressive disorders are pains in joints and the surrounding tissues. However, these pains, for a number of reasons, may not always be present during high altitude flights.

Under identical conditions of rarefied atmosphere, the decompressive pains may appear in one group of people yet be absent in another. In addition, even in one and the same person under the same conditions of rarefaction these pains may be present one day and absent another. In certain persons the decompressive pains appear with each flight to an altitude in excess of 8,000 m and these pains always appear at one and the same altitude and in the same sequence.

Pains of this type may be of varying intensity - from a hardly noticeable sensation in any of the joints or muscles to very acute attacks which may force the pilot to lower his altitude or even terminate the flight.

The practice of high altitude flights and ascents in pressure chambers have shown that decompressive pains are more frequently observed in larger joints and the extremities, chiefly in the knees and shoulder joints. However, the pains infrequently occur also in tendons and in the points of their attachment to the bones, and also intramuscularly.

It should be noted that when in a state of rest, the intensity of the pain is lower and vice versa; with every kind of movement and physical exertion the pains are sharp and more frequent.

Usually, by descending to altitudes of 6,000 - 7,000 m above sea level and lower, the muscular-joint pains disappear but occasionally the feeling of discomfort in the affected joint or muscle and also a state of weakness and exhaustion is retained. All these phenomena disappear fully within a few hours, or in extreme cases after a night's rest.

In addition to the muscular-joint pains, other forms of decompressive disorders are encountered. Rather frequently the muscular-joint /74 pains are accompanied by the appearance of prurience resembling insect bites. More frequently such a prurience is localized on the skin of the spine, breast and abdomen. Sometimes with the appearance of the pains in the joints or the skin prurience, a deterioration in the general well-being of the organism may follow, characterized by weakness, giddiness, excessive sweating, breathlessness and a semi-fainting condition. There is every reason to consider that similar conditions are the results of definite disorders occurring in the central nervous system.

In the majority of cases decompressive disorders appear approximately within 15-20 minutes after ascent to an altitude in excess of 8,000 m and only in singular cases within the first minutes after the ascent. The frequency and intensity of decompressive disorder symptoms depend chiefly on the altitude of the ascent and the length of stay at that height (Tables 9 and 10).

Altitude, m	Number of ascents	% of people experiencing pains	Remarks
10600	92	7.6	
11600	111	55.0	

Table 9

Frequency of the occurrence of the decompressive pains relative to the altitude of the ascent (according to Hitchcock).

Time of stay at an altitude of 10,000 m, min	Joint pains in %
0-10	2.3
10-20	9.6
20-30	16.7
30-40	18.1
In excess of 40	53.3

Table 10

Frequency of the occurrence of decompressive pains relative to the time of stay at a high altitude (according to D. Ye. Rozenblyum).

The fact that certain disorders occur in the human body when transferring from a high barometric pressure to a low one has been known for over 100 years. The phenomenon occurred for the first time in caisson and hydrological works. However, for a long time the cause of these /75 disorders was not known and various explanations and hypotheses were offered.

More recently, the caisson theory has gained general acceptance: the disorders are caused by the transition of nitrogen from the dissolved state in the tissues of the body into the gaseous state if there is a considerable drop in the outside barometric pressure and disorders are caused by the mechanical effect (pressure) of the gas bubbles on the nerve endings, while the bubbles form inside the tissues or as a result of clogging up the fine blood vessels with gas bubbles which form in the blood.

According to the diffusion law, the tissues and the fluids of the body become saturated with gases from the air, since these gases come into contact with the blood in the lungs. The components of the air dissolve in the blood in quantities corresponding to the physical solubility and the partial pressure. It was experimentally established that at atmospheric pressure at sea level about 1.5 cm^3 of nitrogen, 0.36 cm^3 of oxygen and 2.7 cm^3 of carbon dioxide dissolve in 100 cm^3 of blood. The nitrogen dissolves more easily in the fat of the body. At the body temperature about six times more nitrogen becomes dissolved in fat than in the blood. In the blood almost the entire oxygen and carbon dioxide are in the chemically combined state. While most of the oxygen which is dissolved in the blood is consumed by the tissues of the body, the nitrogen is physiologically an inert gas, is not used up by the tissues and is contained in them in the dissolved state in quantities which depend on the partial pressure of the nitrogen in the lungs. At the pressure corresponding to sea level, the tissues will always be fully saturated with atmospheric nitrogen.

At the normal barometric pressure of 760 mm Hg, the tissues of a man of average weight contain about 1 liter of dissolved nitrogen.

When ascending by means of a plane or in other situations in which there is a drop in the atmospheric pressure in the external atmosphere, the partial nitrogen pressure in the tissues of the body will be higher than in the lungs and the tissues will thus be saturated with nitrogen. As a result of this, the nitrogen dissolved in the body, according to the Dalton law, will start to flow into the lungs and the nitrogen from the tissues will flow into the blood stream. By these means the body frees itself from the excess nitrogen. If the increase or decrease in pressure in a pressure chamber is so slow that the excess nitrogen can be rejected by the body through the lungs, no /76 disorders will occur at all. However, if the drop in the barometric pressure (decompression) is fast, the excess nitrogen will not manage to flow from the tissues into the blood and from the blood by means of diffusion through the lungs into the external atmosphere and the nitrogen dissolved in the blood or tissues will become transformed into the gaseous state, forming gas bubbles and causing disorders. It is assumed that during decompression bubbles will form at first which consist of CO_2, into which nitrogen then diffuses. Later on, the quantity of nitrogen in the bubbles becomes predominant.

Other gases which enter into the composition of the air, which are dissolved in the tissues of the body in negligibly small quantities, have no significant practical importance in causing decompression troubles.

Numerous investigations have shown that the formation of bubbles begins at the instant when the nitrogen concentration in the body is over twice its normal saturation value at the given barometric pressure.

The occurrence of decompression disorders during flight begins at an altitude of 8,000 m. This is due to the fact that at the atmospheric pressure of 266.86 mm Hg at this altitude the critical moment occurs when the concentration of nitrogen in the body is twice as great as the saturation level which would be normal for this pressure.

As was mentioned earlier, decompression disorders manifest themselves some time after reaching altitudes in excess of 8,000 m. This is explained by the fact that for the formation and growth of bubbles during decompression a certain time is required. This time will be the shorter the higher the degree of saturation and the shorter the period of decompression.

The highest number of bubbles form in those tissues of the body which contain a great quantity of fat and have a poor blood supply. Since the removal of nitrogen from the tissues is basically through the blood circulation, the parts of the body or tissues which have the poorest blood supply have the worst conditions as regards rapid elimination of excess nitrogen. The occurrence of pain is in the first instance in the joints, which is explained by the fact the the joint pouches have a very poor supply of blood vessels.

Numerous authors believe that the frequency of occurrence of decompression disorders is also influenced by other factors. /77

Any weakening of the body caused by overtiredness, disease, inadequate sleep, alcohol consumption, excessive smoking etc. will produce more frequent decompression disorders in a more pronounced form and at lower altitudes.

Physical stress during residence at high altitudes doubles the frequency of cases of decompression disorders and their intensity (Table 11).

Height, m	Speed of rise (of pressure drop)		
	35 mm Hg/sec	104 mm Hg/sec	208 mm Hg/sec
11,600 (without physical effort)	7.6	24.2	33.3
11,600 (with physical effort)	55.0	62.2	67.6

Table 11

Frequency of decompression disorders as a function of the speed of decompression and the physical load.

Fat adults and tall people suffer more frequently from decompression disorders than slim or short people.

Older people suffer from decompression disorders more than young people. This is due to the fact that the blood circulation is poorer and the removal of nitrogen through the lungs is lower in fat, tall and old people.

Among the factors which facilitate the manifestation of decompression disorders the overall and local super-cooling may have some effect, as well as excessively tight and unsuitable clothing which impedes the movements and causes retentive phenomena.

In the case of prolonged stays at altitudes in excess of 12,000 m, decompression disorders will occur more frequently.

In addition to what was said above, under conditions of rarefied atmosphere at altitudes of 9,000-20,000 m, boiling of the semifluid media of the body may occur, which is accompanied by a mass vapor formation in the tissues and cavities of the body.

Mass boiling of liquids in the tissues should bring about an increase in the volume of the body. /78

In experiments with animals in an atmosphere with a pressure below 50 mm Hg, formation of bubbles under the skin (high altitude emphysema) is observed, these are filled with water vapor and gases which are dissolved in the fluids. This phenomenon is due to boiling of the semiliquid media of the body at low barometric pressures (Table 12).

Altitude, m	Barometric pressure, mm Hg	Boiling temperature of the water, °C
0	760	100.0
2000	596	92.5
4000	462	85.5
6000	354	79.0
8000	268	72.5
10000	198	65.5
12000	145	58.5
14000	106	51.5
16000	77	46.0
18000	56	39.5
20000	41	35.0
25000	19	22.0
30000	9	10.0

Table 12

Dependence of the boiling point of water on the temperature and the barometric pressure.

According to the laws of physics, every liquid boils at a moment when the vapor pressure of this liquid exceeds the internal pressure as a result of increase of temperature or as a result of lowering the internal pressure or, finally, when two of these phenomena take place. Theoretically, one should expect that the same phenomena should occur in the case of liquid tissues at their usual temperature of approximately 37° C if the atmospheric pressure will fall to the level of the vapor pressure of these liquids, that is 47 mm Hg, which corresponds approximately to the altitude of 19,000 meters.

Verification of theoretical calculations in experimental conditions using animals, confirms the correctness of these calculations. At an altitude of 19,000 meters animals develop separate swellings on their skin which later on coalesce into continuous swellings; also it is possible to observe (in a specially built for the purpose chamber) the so- /79
called "boiling" of blood. On descending to the height of 18,000 meters and lower, all these phenomena disappear.

The experimental data show that the phenomena of boiling and vapor formation may be observed not only in the subcutaneous tissue and in the blood, but also in the abdominal cavity, in the pleural cavities, in the heart and the muscles.

At a height of 20,000 m, separate subcutaneous swellings appear within 2 - 3 seconds and within 7 - 10 seconds the subcutaneous emphysema becomes continuous and reaches its peak.

It should be noted that in the case of even more rarefied atmosphere the decompressive swellings are even greater and they appear within a much shorter time.

In contrast to the statements of foreign authors about the inevitable death of the organism in similar conditions, Soviet investigators (A. G. Kuznetsov and others), supported by their experimental data, think otherwise. All animals in which they observed acute symptoms of boiling and vapor formation in their bodies, as a rule survived if the duration of their stay in the rarefied atmosphere (40 - 30 mm Hg) did not exceed 2 minutes. Otherwise, the animals would die not as a result of the formation of vapor, but from acute oxygen starvation, within the same period of time as they would have died at altitudes of 17,000 - 18,000 meters - altitudes at which the phenomena of boiling within the tissues of the animals are not observed. However, one must not state that in themselves these phenomena are harmless for the organism. There is reason to think that although without immediate danger to life, they act both locally and through the nervous system by way of reflexes, and may cause not only temporary reversible physiological changes in the function of the more important organs, but also leave permanent traces of far-reaching irreversible changes in the structure of such organs and tissues of the body as the heart, blood vessels, nervous tissue, and others.

In connection with these problems, the development of means capable of protecting against such phenomena becomes of great importance.

Naturally, the chief requirement which may be used in this type of protection is the need to contrive means of creating additional pressure on the surface of the body, sufficient in value to protect against the development of the phenomena of the decompressive swellings.

The extent of such pressure should be expressed by a relatively small quantity which together with the value of the atmospheric pressure at the height of flight should slightly exceed 47 mm Hg, that is, the pressure at which occurs the boiling of the liquids of the living organism with a body temperature of +37° C. /80

The effect of the additional pressure could be achieved with the help of the so-called pressure suit which covers all the body.

Prophylactic Measures

One of the most suitable means of fighting the decompressive disorders at high altitude is the pressurization of the airplane's cabin. Pressure in pressurized cabins should not fall below 268 mm Hg, that is, corresponding to the height of 8,000 meters. In the pressurized cabin of the modern fighting plane, pressure is controlled automatically in relation to the altitude by exceeding the ambient atmospheric pressure by 230 - 300 mm Hg.

In order to protect against the decompressive disorders, together with the pressurized cabins, high-altitude scaphanders may also be used successfully. These safety scaphanders, similarly as the pressurized cabins, secure round the pilot higher pressure than the ambient atmospheric pressure and thus prevent the possibility of development of the decompressive disorders, up to the altitudes at which the pressure in the scaphander will be not lower than 268 mm Hg.

In order to prevent the occurrence of the compressive disorders, nitrogen desaturation of the body may be recommended by inhaling pure oxygen for a period of 30 - 35 minutes prior to the flight. Oxygen apparatus as used in modern aviation may be used for this purpose. The main point of nitrogen desaturation of the body lies in this, that during breathing with pure oxygen the partial pressure of nitrogen in the alveolar air falls very rapidly, as a result of which there is a difference between the partial pressure of nitrogen in the alveolar air of the lungs and its pressure in the venous blood entering the lungs.

According to the laws of diffusion, the excess of nitrogen passes from the blood into the alveolar air and is vented into the atmosphere with each expiration. Upon its return into tissues, the blood again saturates itself with nitrogen and hence again follows into the lungs where the process of desaturation is repeated. With each circulation of blood the pressure of nitrogen in the tissues and in blood lowers itself and the desaturation is slowed down. When breathing with pure oxygen, one third of the nitrogen which has been dissolved in the tissues /81 is eliminated from the organism within the first 15 minutes, and the remaining two thirds within a very long time. Full desaturation of the body from nitrogen takes up to 10 - 12 hours. Many of the investigators consider that absolute removal of nitrogen from the body cannot be achieved since with the considerable lowering of nitrogen pressure in the tissues, nitrogen from the ambient atmosphere diffuses through the skin in small quantities into the tissues.

The efficiency of nitrogen desaturation of the organism depends on the duration of breathing with oxygen and the height of the ascent.

As a result of the preliminary desaturation of the body from nitrogen, the frequency of the decompressive disorders is lowered and so also is their intensity.

Since muscular effort during the stay at the altitude enhances the appearance of the decompressive disorders, one should as far as possible automatize all the work of the flying personnel.

In addition to what has been said before, in order to avoid the decompressive disorders the flying personnel should observe a suitable regime of rest and diet with special care, prior to their high altitude flight.

The Effect of Rapid and Great Barometric Pressure Falls on Human Organisms

Aviational practice differentiates between the slow, and the rapid or so-called explosive decompression (fall of pressure). Slow decompression is observed in each flight since the barometric pressure in a pressurized cabin is falling gradually with increasing altitude according to the pre-determinded conditions of pressure change in the pressurized cabins of a given type. This fall of pressure is considered to be a normal phenomenon.

However, in contemporary high-altitude aviation, a collapse of gastight seal in a pressurized cabin may cause very considerable falls in barometric pressure (decompression), and the pressure may fall within an interval from a few seconds to within a fraction of a second. In the case when a large hole is formed in the cabin, or if the cabin is completely destroyed, the decompression will as a rule be of an explosive nature. All these circumstances led to the necessity of studying the effects of large and rapid barometric pressure falls on human organism.

The effect of barometric pressure fall upon the human body is determined in the first instance by the height of the flight at which the pressurization of the cabin has been disrupted. If the cabin was depressurized at an altitude in excess of 12,000 meters, flying personnel is exposed to the danger of acute oxygen starvation. The danger will be the greater, the higher the altitude at which the pressurization was destroyed. /82

However, in recent years oxygen-breathing apparatus has found wide applications in aviation. In this apparatus oxygen is fed into the respiratory tract, with the simultaneous use of the pressure suit, which extends over the whole body, offering a counter-balance to the excess pressure inside the lungs. This type of oxygen apparatus makes it possible for the flying crew to exist and be capable of work at any altitude after the fall in barometric pressure.

In addition, in the case of decompression of the cabin, high-altitude scaphanders may also be used at altitudes of 30,000 meters and more, but in this case the time of staying at such altitudes is limited.

Next, one should consider separately the mechanical effects of the large and rapid falls of barometric pressure which occur during the collapse of the pressurization of the cabin.

One of the symptoms of the mechanical effect of pressure fall at high altitude is the swelling of the abdomen which is caused by the expansion of gas entrained in the gastrointestinal tract. When the barometric pressure falls, the volume of gases in the gastrointestinal tract increases proportionally to the degree of the fall.

Approximate data about the increase of gas volumes at altitudes during an unrestricted swelling are give in Table 13.

Altitude in m	Pressure in atm	Comparative volume of the gas
0	1	1
5500	1/2	2
8400	1/3	3
10300	1/4	4
11600	1/5	5
12400	1/6	6
14000	1/7	7
16000	1/10	10
20000	1/20	20

Table 13

The actual expansion of the gases in the gastrointestinal tract during the time of high altitude flight is sometimes not so great as is shown in Table 13. This is explained first by the fact that within the cabin there is sustained slightly higher pressure than in the ambient atmosphere, and secondly, due to the elastic resistance of the gastrointestinal tract and abdominal wall. /83

The expanding gases during the fall of pressure extend the walls of the stomach and gut, and by virtue of their pressure, irritate mechanically the sensory nerve endings located there. This causes a sensation of pain in the abdomen.

The frequency and intensity of the pain in the abdomen increase with increased pressure fall and its rapidity, particularly if there was a disturbance in the pre-flight diet. Acute abdominal pain may be the cause of the following general deterioration in the general condition: feeling of weakness, cold sweat, slowing of the pulse, nausea, vomiting, near fainting, and also cause dangerous reflexes which depress the action of heart and other organs. Against this background one may also observe not infrequently, depression of the function of the central nervous system and lowering of the general working capacity.

The nature of the mechanical effect of the barometric pressure fall upon the human body depends on the following factors:

1. The amount of the pressure fall, which is determined by the difference of the pressure in the pressurized cabin before the beginning of decompression and after its full conclusion. However, a pressure fall from, say, 760 to 127 mm Hg may cause greater deforming action than for instance a pressure fall from 380 to 63 mm Hg, although in both cases the ratio of the initial pressure to the final was the same, namely 6.

2. The duration of time of pressure fall is determined by the time interval from the beginning of the pressure fall to the moment of complete equalization of the pressure within the cabin of the airplane with the pressure in the ambient atmosphere. The time interval of the pressure fall is expressed in seconds or in fractions of a second.

3. The rate of pressure fall indicating the quantity of the pressure change in the cabin, in mm Hg per second. Usually, the time of fall and its rate are in inverse relation. The greater the time of pressure fall, the smaller will be the rate of fall, and vice versa.

It is obvious that the smaller the initial amount of pressure and the longer the time of fall of pressure and smaller its rate of fall, the easier it will be for the organism to withstand it. /84

For the purpose of prophylaxis of the untoward effects of pressure fall at high altitudes, it is necessary to eliminate the use of products which lead to the formation of a large quantity of gases: beans, fruit, gruel, etc. It is also recommended to empty one's bowels immediately before the flight; this applies particularly to people who have a tendency to flatulence.

In most cases the inflation of the abdomen is somewhat reduced within the few seconds from the beginning of the pressure fall, due to the passing of gases from the intestine via the anus, and from the stomach by means of eructation. After this venting, pains arising from the flatulence quickly disappear.

On the basis of analysis of numerous experimental observations carried out in the Soviet Union and abroad it may be concluded that for the human gastrointestinal tract, pressure falls from 760 to 198 mm Hg (the altitude of 10,000 meters) occurring within one second, are fully tolerable.

However, if the pressure fall occurs not from the initial pressure of 760 mm Hg but, say from 308 mm Hg (altitude 7,000 meters), it is even easier to endure. In such conditions, pressure falls occurring within a hundredth of a second at altitudes from 15,000 to 20,000 meters and more, are fully permissible and will not cause any untoward effects in the gastrointestinal tract.

In the case of greater and faster pressure falls, air contained in the lungs is suddenly expanded and consequently its volume increases, as a result of which the intrapulmonary pressure may increase to a certain higher level briefly in relation to the ambient pressure.

During the decompression, as a result of the sudden expansion of air in the lungs a sensation is experienced similar to a blow on the chest. The warm alveolar air is rapidly exhaled and the pressure in the lungs falls. The process of leveling the pressure in the lungs with the ambient atmospheric pressure is continued within one to two seconds after the pressure fall.

The probability of mechanical injury of the lung tissue as a result of the action of the decompressive pressure fall of an explosive character depends on a number of factors and conditions.

In this case, the rate and degree of pressure fall is of fundamental importance, as is also the initial pressure in the lung, i.e. the density of air before the beginning of the pressure fall. The faster and the greater is the fall of pressure (particularly in the case of considerably high value of the initial pressure), the greater is the danger of injury to the lungs. /85

Equally important is the phase of respiration during which the pressure fall occurs, the state of the trachea, bronchi, and the lung tissue itself. The presence of resistance to the expiration as the result of inflammatory processes in the lungs and respiratory tract accompanied by the accumulation of mucus in them, increases the danger of lung injury during rapid fall of pressure. If the pressure fall occurs during the phase of inspiration it becomes somewhat more difficult for the body to tolerate the pressure fall than in the phase of expiration.

One of the reasons impeding the free expiration of air from the lungs during a rapid pressure fall is the oxygen mask. For that reason, for a long time a number of investigators had different opinions and were pointing to possible dangers. However, the results obtained during recent years as a result of numerous experiments did not substantiate these forebodings and today the use of hermetic masks is accepted as completely safe.

Traumatic injury of lungs during rapid pressure falls may occur only when the excess internal lung pressure reaches a value exceeding the limit of the mechanical strength of the lung tissue.

Experiments on animals have established that traumatic injury of lungs is observed only in those cases when the internal pressure exceeds the pressure of the ambient atmosphere by 60 - 80 mm Hg in the absence of counterpressure acting from the surface of the chest. In these circumstances the pressure falls occurring during the end of inspiration are the most dangerous as they coincide with the moment of greatest extension of the lung tissue.

During investigation of the injured lungs of the animals exposed to the action of extremely high and rapid barometric pressure falls, singular and multiple hemorrhages were found on the surface deep within the lung tissue, and ruptures of the lung tissue were also found.

When considering the experimental data about the mechanical strength of the lung tissue of animals, one should remember that the strength of lung tissue of human beings is considerably greater than that of an animal.

In human beings, even in ordinary daily routine, there are frequent situations in which an excess pressure inside the lungs occurs, which may reach 100 mm Hg and more (for instance, in the case of coughing, sneezing, great physical strain, etc.). However, these do not lead to any untoward phenomena, nor is there any injury of the lung tissue. /86

Numerous experimental studies on animals (dogs) showed that with the pressure falls from sea level to an altitude of 12,000 meters during 3 - 4 seconds, there is no likelihood of danger of injuring the lung tissue.

With pressure falls from sea level to altitudes of 12,000 - 17,000 meters during 1 - 2 seconds with a following rapid descent to earth, hemorrhages of various sizes were very frequently found in the lungs. These hemorrhages ranged from very small to considerably large ones extending over a whole lobe.

These preliminary tests on animals established the critical velocities of pressure falls. The results obtained made it possible to carry out the investigation of pressure falls in human tests. In these experiments, pressure falls from 760 to 268, 198 and 145 mm Hg (from ground to 8,000 meters, 10,000 meters and 12,000 meters), and also from the altitudes of 3,000 - 7,000 meters up to 10,000 and 15,000 meters and more were investigated. In the interests of safety the tests were started with pressure falls lasting for a number of minutes. Gradually, the duration of pressure falls was shortened to tens of seconds and finally to fractions of a second.

As a result of these tests it was found that the pressure falls from ground pressure up to that of an altitude of 10,000 - 12,000 meters during 3 - 4 seconds may be endured by people quite comfortably and the danger of injury to lung tissue is very unlikely. During the pressure falls the subjects noticed rapid inflation of the abdomen and also extension of the chest. In isolated cases the rapidly increasing abdominal swelling and the extension of the chest were perceived by the subject as if he had received a blow in these regions.

The pressure falls from 3,000 to 7,000 meters up to the altitude of 10,000 to 15,000 meters were carried out in the final total for a period of one second and less.

X-ray investigations after similar pressure falls showed that there were no changes in the lungs in the great majority of the tests, and only in very rare cases were there found extremely minute fractions of the lung tissue which were darkened, which within a matter of a few days disappeared without any trace or any harm to the health of the subject.

Small quantities of air are contained in the cavities of the middle ear and in the nasal sinuses. The above cavities are connected by special ducts with the nose and the gullet. Air is exchanged through these ducts between the above cavities and the atmosphere. /87

During rapid changes of barometric pressure of the ambient atmosphere during high altitude flight the pressure in the cavities of the external ear canal and of the nose changes at the same rate as the barometric pressure. The middle ear (tympanic cavity) is connected with the ambient atmosphere by means of a very narrow channel (Eustachian tube) which often has a torturous structure. Therefore, during rapid changes of barometric pressure in the ambient atmosphere the pressure in the tympanic cavity levels itself off at a slower rate than is necessary. In this way the tympanic cavity develops positive and negative pressure which causes mechanical irritation of the surrounding tissues and impairs the blood circulation; unpleasant sensations appear such as the feeling of pressure, of stuffiness and of a buzzing noise in the ears and also of pain of varying intensity.

All these phenomena are more frequent and more acute in the case of inflammation of the upper respiratory tract and anatomic changes in the Eustachian tube.

As a rule, the above unpleasant sensations in the ears appear during the pressure fall from a fraction of an atmosphere to the earth pressure, during which the pressure in the tympanic cavity cannot manage in time to level itself with the atmospheric pressure. When these phenomena take place, a partial vacuum is created in the tympanic cavity as a result of which the blood vessels in the mucous membrane lining these cavities are over-filled with blood which causes painful sensations. These pains in the ears are most likely to occur in the layers of atmosphere with greater density, namely at altitudes of 3,500 meters and below.

In the case of comparatively slow pressure falls during the ascent to altitudes, the unpleasant sensations in the ears were not observed in the absolute majority of cases. If they do occur, then this is very seldom and only in persons with some or other pathologies of naso-pharynx or the middle ear. In the case of very fast pressure falls of an intensity corresponding to the explosive decompression, there may occur sensations in the ears such as the feeling of pressure, of blocking, buzzing noise, and sometimes also of pain. These are caused by the mechanical irritation of the expanding air in the tympanic cavities, the pressure of which did not manage to level itself off with the ambient pressure of the atmosphere.

Similar phenomena during the barometric pressure fall in the ambient /88 atmosphere may occur also in the frontal sinuses. The reason for these phenomena is the slow leveling of the air pressure within these sinuses with the pressure of the ambient atmosphere.

The appearance of this type of pain in the ears and frontal sinuses recedes in most cases immediately after the flight and only seldom is retained for a few hours, and in a very few cases for a number of days.

With greater and faster falls of barometric pressure occurring within a second or a fraction of a second, favorable conditions are created for the appearance of decompression disorders, particularly if the subject did not use the oxygen apparatus before the pressure fall.

CHAPTER V

PRINCIPAL HYGIENIC REQUIREMENTS OF THE AIRPLANE'S CABINS /89

The cabin of an aircraft is the working place of the crew. During the development of aviation and aircraft design the construction of the cabin underwent radical changes. The first flying machines had practically no cabins or instruments. The pilot occupied a very primitive and completely open seat and was exposed to the unimpeded effect of the air stream and other meteorological conditions. The altitude, velocity and duration of flight were in those days quite inconsiderable; hence there was no necessity for building the cabin. However, with the increasing velocity of flight came the necessity for protecting the pilot from the impingement of the air stream. Already at the velocity of 40 kilometers per hour there is a definite perception of air pressure on the body and breathing is somewhat impaired, while there is also a considerably increased loss of heat. At velocities of 250 kilometers per hour and above, the air offers such a great pressure on the chest, face and abdomen that breathing becomes impossible. These reasons necessitated the construction of a special cabin protecting the crew of the aircraft from the action of the impinging air-stream.

Further increases in the altitude, velocity and duration of flight caused the aircraft designers to adopt a cabin of a closed type which would protect the pilot much better from the direct effects of all the factors of the external medium. In the closed cabin the pilot found himself in a more favorable condition and his working capacity and combat capability improved considerably. During recent years, high-altitude /90 aviation widely adopted the use of pressurized cabins, which secure not only protection of the pilot against the action of air pressure and other meteorological factors but also sustain a barometric pressure within the cabin which exceeds the pressure in the ambient atmosphere at the height of the flight.

The cabin of the aircraft is of great interest. The quality of the design of the working place of the pilot is determined by the following: the dimensions and design of the cabin itself; the arrangement of the pilot's seat; the arrangement of the seat belt; design and layout of the instruments and control equipment; position of the oxygen apparatus; illumination of the instrument panel and the cabin; the degree of visibility from the cabin; physical state and chemical composition of the air in the cabin, and others.

The main requirement for all the cabins of the aircraft is the creation of the most comfortable and hygienic working conditions for the pilots during flights.

It is fully understood that the requirements of the working place of the aircrew will vary according to the nature of their work; for instance, the requirements of the working place of the pilot will differ from those of the working place of the navigator, gunner-radio operator, and others.

The dimensions of the cabin are of great importance to the work of the pilot.

In order to improve the aerodynamic qualities of the aircraft the designers are inclined to reduce the dimensions of the cabin. However, this tendency clearly conflicts with hygienic requirements. A tight cabin makes the pilot's work more difficult, limits his movements and makes his escape, in the case of an accident in the air, more difficult.

The larger and the more spacious the cabin of an aircraft, the less constrained are the movements of the members of the crew and the less likely is there a chance of injury due to collision with contents of the cabin in the case of occasional bumps in the flight or during emergency escape by parachute or by ejection, etc.

Aircraft with a large number of seats and large radius of action should be equipped with cabins permitting free movement of the members of the crew inside the plane. A place for the rest of the crew members should also be envisaged in the planning of a cabin.

The maximum permissible dimensions of the cabin of an aircraft are determined by the extent of the working movements of the pilot and also by his dimensions, viz. height, shoulder width, width of pelvis, length of legs, etc.

The necessary data for this purpose were obtained by exhaustive measurements on flying personnel over a period of many years. For instance, according to the data of N. M. Dobrotvorski, the maximum shoulder width of pilots does not as a rule exceed 45 cm. This is clear from Table 14, which was compiled on the basis of a large number of anthropometric measurements. /91

Shoulder width of pilots, cm	% of pilots
up to 30	0.6
31 - 35	5.7
36 - 40	72.6
41 - 45	21.1

Table 14

In order to establish the minimum permissible width of the cabin, that is the distance between the protruding parts on the two opposite sides, the thickness of the winter uniform (10 cm) and an additional 20 cm clearance was to be added to the maximum shoulder width of 45 cm. In this way the minimum width of the cabin between the sides is taken as equal to 75 - 80 cm.

The height of the cabin, that is the distance measured from the level of the boards underneath the pedals to the upper point of the skylight, should be not less than 125 cm. This height will ensure that the pilot can adopt a comfortable position during his work. In order to calculate the height of the cabin, maximum height of the seat is taken as 98 cm, plus the thickness of the uniform and certain height to spare (Table 15).

Height of pilot's seat, cm	% of pilots
80 - 84	2
85 - 89	41
90 - 94	53
95 - 98	4

Table 15

Taking into consideration the nature of navigators' work, the height of the navigator's cabin should be not less than 130 cm. In the aircraft, in which there is inevitable communication between the members of the flying crew from one place to another, the height of the cabin should be not less than 140 cm.

Members of the flying personnel who work in a standing position should have the height of the cabin not less than 170 cm. In these circumstances, members of the flying personnel who are small in height should be provided, for the sake of comfort, with foot stools. /92

The longitudinal dimensions of the cabin, that is the distance from the back of the seat to the instrument board, are determined by taking into consideration the comfort of the working position of the pilot and the good visibility of the instrument board. The further the instrument board is from the pilot the greater is the number of instruments which he can observe simultaneously. However, if the instrument board is too far away, it causes certain difficulties in the observation of the instrument and makes the pilot strain his eyes. By experiment it was determined that the best way of placing the instrument panel is at a distance of 75 - 95 cm from the center back of the pilot's seat.

Recently, in connection with the necessity of protecting the flying personnel during accidents in the air by means of ejection from the aircraft, which is carried out by ejecting the pilot from the cabin of the aircraft together with his seat, the dimensions of the cabin were somewhat increased in order to avoid injury during ejection. In order to avoid injuries during flight, during emergency landings and when leaving the aircraft, the cabin should not contain any unnecessary parts, protrusions etc. which may cause injury and wounds. The sightings, the protruding parts and details, angles, edges etc. should all have soft, shock-absorbing coverings.

All levers, controls and handles should be actuated simply without considerable force or strain, by a gentle pressure of the hand.

The cabins of aircraft should also have a place envisaged for keeping first-aid kits and some stores of emergency supplies so arranged that the members of the flying crew could freely use them in the case of emergency.

The seat of the pilot is one of the most important elements of the aircraft cabin. It should be designed with due regard to the nature of the work of the members of the crew and should also fulfill the following physiological and hygienic requirements: correspond to the dimensions of the body; secure comfortable control over the aircraft and easy observation of the outside area and the instrument board; permit maximum possible relaxation of the muscles and prevent excessive fatigue of the pilot; it should not cause disturbances in the blood circulation and respiration; it should offer a high stability during accelerations; and finally, it should permit emergency abandonment of the aircraft.

The smallest muscular tension and the most comfortable position for working can be attained if the trunk is leaning slightly backwards at an obtuse angle with respect to the hips and the seat (Figure 14). /93

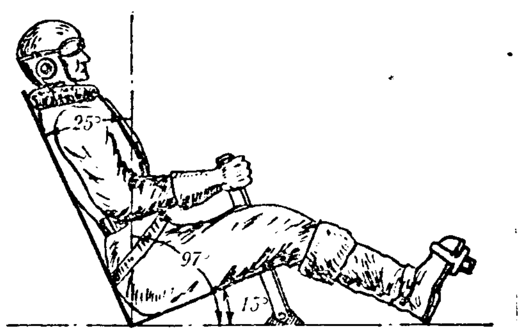

Figure 14. The Proper Arrangement for the Pilot's Seat (according to N. M. Dobrotvorski).

This inclination of the back of the seat relieves the excessive strain from the muscles of the trunk and at the same time considerably increases the resistance of the body towards accelerations. However, for constructional reasons contemporary aircraft have the inclination of the back of the seat fixed somewhat below 25%. (Translator's note: This is obviously a mistake; it should read 25°). The width of the seat, as well as the dimensions of the cabin, are calculated from the maximum width of the pelvis and reach 40 - 43 cm. The depth of the seat is usually of the order of 38 - 40 cm. As a rule the seat is of the bucket type. Its dimensions and shape correspond to the dimensions and shape of the folded parachute. However, recently, in a certain type of aircraft the parachute is placed not in the bucket of the seat but behind its back in a special container. The back of the pilot's seat should shape properly to the position of the spine.

The height and the width of the back should be sufficient to protect the pilot from enemy fire from behind . In the upper part of the back of the seat there is attached a headrest, and elbow-rests over the seat.

The seat, the seat back and the headrest should all be covered with cushioning material of soft sponge rubber or of hair, in order /94
to eliminate any pressure of metallic parts on the body of the man sitting in it, and give the seat a more comfortable shape.

The height of the seat in modern aircraft is adjusted according to the height of the occupant, and the distance from the pedals to the seat can also be adjusted. During the flight, legs should be slightly bent at the knees in order to prevent early tiredness and disturbances in the blood circulation.

Long-range aircraft should have the seats of the crew arranged in such a way that they provide maximum comfort during work and during rest.

Modern military aircraft of all types are equipped with special ejection facilities.

Belts attached to the seats of the crew form an integral part of the seats. Their great importance was learned during the Second World War, when their use considerably reduced injuries among flying personnel. Their importance in modern military aircraft has become even greater. During emergency landings when the fuselage comes into contact with the runway at high speeds, the crew is exposed to bruises and injuries. In these conditions, safety belts hold the bodies of the crew in their seats and protect them from hitting the instrument board and other objects in the cabin. The shoulder straps are of great importance in preventing or reducing injuries during rapid deceleration of the aircraft, and they are attached strongly to the back of the seat at the level of the shoulder blades, while the waist belts are attached at the level of the loins. The safety belts must be of sufficient strength, and their width not less than 60 mm. They should not cramp movement or interfere with normal blood circulation and respiration. The adjustment of the length of the safety belt is carried out according to the height of the wearer. The clasp of the safety belt locks all the ends of the straps simultaneously, and its opening and closing are very simple. The design of the lock and the attached straps is standardized and applies to all types of aircraft. All members of the crew are equipped with these safety belts.

The aircraft controls, such as the joystick and the rudder bar, should not obscure any of the instruments in any position. The distance between the joystick and the rudder bar (in the extreme position towards the pilot) and the back of his seat does not exceed 35 - 38 cm.

Particular attention should be given to the standardization of the distances of levers, handles, bearing sectors and toggle switches in aircraft of all types, and particularly in aircraft of one type and various subsequent production series. Non-standard positioning makes the work of the flying personnel much more difficult and may also cause some flying accidents.

The modern type of aircraft carries an extremely large number of all kinds of instruments and devices which make it possible to fly at very high altitudes and at very high speeds, for hundreds and thousands of kilometers in any kind of weather conditions. The observation and adjustment of the indicators of such a large number of instruments during many hours of flight require from the flying personnel extraordinary concentration, which in turn dissipates a lot of strength and energy. All these factors compel one to carry out extensive standardization of the position of the instruments, taking into consideration the designation of the aircraft, the peculiarities and possibilities of the human organism. The principle of the disposition of instruments accepted at present is based on the experimental evidence of the designers, pilots and the aviation physicians. However, it should be mentioned that these principles need further study and standardization. /95

The instruments and organs of control should be disposed in such a way that the main instruments and devices are placed in the most accessible places. Under normal flying conditions the pilot should not divert his attention in order to observe instruments which need only occasional attention. These instruments should be equipped with light or sound signaling, in order that they could attract the attention of the pilot if they approach a critical position. This type of instrument distribution allows the pilot to concentrate all his attention on the fundamental instruments, which leads to a more rapid fulfillment of the flight schedule.

The instrument panel should be well visible to the pilot without any strain on his eyes. It should be mounted at right angles to the longitudinal axis of the aircraft. In order to avoid injuries to the knees, the lower edge of the instrument panel should be at a distance not less than 45 cm from the level of the boards underneath the pedals. The instruments themselves should be placed at a maximum recess and should not protrude beyond the surface of the instrument panel. The positioning of the instruments on the panel has been determined as a result of many years of practice, according to which the major aero-navigational instruments and the instruments controlling the operation of the engine, the radio equipment, and the electricity generator, are placed in the center of the instrument panel in the field of vision of the pilot whatever the type of aircraft. On the right hand control desk should be placed the corre- /96
sponding levers and toggle switches. In bombers, the number of instruments which are under continuous observation of the pilot is considerably smaller than in fighters, since most of them are under the observation and control of the navigator, engineer, and gunner-radio telegraphist. In studies of the most advantageous receptivity of the instruments' indication it has been shown that the most suitable color for the instruments is a matt black, and the thickness of the scale divisions of the instruments should be from 0.45 to 0.60 mm. The illumination of the instruments and the instrument panel, regardless of the accepted illumination system, should be capable of continuous intensity adjustment. The equipment and the disposition of the illuminating system should exclude the possibility of light reflections and flashes of light on the glass covers of the instruments and lights which cause glare.

The work of the engines gives rise to noise and vibrations of different intensity, which have a definite effect on the flying personnel and also on the people servicing the flight.

The noise may differ greatly according to its physical nature. The main sources are in the case of jet aircraft, the jet engines; and in the case of piston planes, the propellers and the engine assembly. The intensity of noise radiating from piston aircraft on the ground with the engines working is 115-120 decibels at a distance of 5 m from the propeller; the corresponding noise from aircraft with jet engines is 140 decibels. The noise level in the cabin falls to about 80 - 110 decibels, and the degree of lowering of this noise level depends on the type of aircraft and type of cabin. The greatest reduction in noise level is achieved in hermetically sealed cabins, that is, pressurized cabins, which have a special layer of sound-absorbing material.

The effect of the noise on the human body depends mainly on its intensity and duration. Noises of intensities below 80 decibels do not cause any lowering of the working capability of a human being; noises of 80-100 decibels lower the working capability only for certain people.

In the majority of cases, within these margins, the working capability of most people is not lowered due to the considerable physiological adaptability to such noises. As the intensity of the noise increases, its effect on the working capability and the state of the whole body increases. The most intensive sounds approach the threshold of pain sensibility, and this occurs at approximately 130 decibels. Noise of approximately 150 decibels cannot be tolerated by human beings, and intensities reaching 160 decibels may lead to perforation of the ear drums and may also affect the middle ear. /97

There is evidence that, depending on the intensity and type of noise and the nature of the work being carried out, noise lowers the performance capability within the range of 1 to 20% . A persistent steady noise appears to have less effect on the organism than an irregular one. If the human ear is subjected to a sufficiently long or repeated very loud noise, then a temporary loss of hearing may occur which, in some cases, may prove to be permanent. Resistance to this factor varies in different people, the limits of variations being very wide.

A person who is subjected to a noise of 90 decibels for 6-8 hours develops a moderate reduction in hearing which disappears within approximately one hour after termination of the noise. After being subjected for a number of hours to conditions of noise with the intensity of 115 decibels, temporary loss of hearing follows in the region of the middle and upper frequencies, which may last from a few minutes up to a few hours. Noise of an intensity exceeding 120 decibels very quickly causes fatigue, within 10-15 minutes, and is accompanied by considerably reduced hearing. Permanent impairment of hearing is very seldom encountered among flying personnel. Most pilots who have been flying for many years have excellent hearing; only some experience a short spell of reduced hearing during the flight.

In addition to noise, the human body is also exposed to vibrations, which may vary as regards amplitude and frequency of vibration per unit of time. Strong and prolonged vibrations may cause vibrations of the organs and tissues, and in this way cause untoward effects in the whole human organism. The response of human beings to the effects of vibration varies from one person to another. Some people have extremely good resistance; others very rapidly develop a state of fatigue. Vibrations in aircraft are within the range of tolerance of human beings.

The reduction in the intensity of vibrations in aircraft is achieved by equipping it with special devices which have definite periods of vibrations and which therefore either reduce or eliminate completely the vibrations.

Particularly important factors affecting the pilot during flight are his physical conditions and the compostion and temperature of the air in the cabin of the aircraft. /98

The human organism is particularly sensitive to changes in the ambient temperature. All biological processes within the body can progress normally only when variations in the temperature of the body are small. If the temperature of the body drops by 1-2° C the protective mechanisms of the body are considerably lowered, which is very often the main reason for catarrhal diseases.

The sensitivity of a human being towards increased temperature is even more pronounced. Increase in temperature, due to overheating, of the body by 1-2° C causes an increase in the pulse rate, copious perspiration, headache and sometimes vertigo and nausea. Further overheating of the body may cause heat stroke, the result of which leads to a comatose condition and sometimes to convulsions and to deep disturbances in the respiratory and blood circulatory systems.

It is clear from the above that the retention of constant temperature is of paramount importance to the health of a human being and his working capability.

During the many thousands of years of its evolution, the human organism adjusted itself to considerable fluctuations in the temperature of the external medium. Constant body temperature is maintained by means of regulating mechanisms which are under the control of the central nervous system. When the temperature of the external medium falls, oxidizing processes are increased and at the same time the rejection of heat into the external medium is reduced, in order to keep the temperature constant within the organism.

When the ambient temperature of the medium increases, the reverse is true. The intensity of the oxidizing processes decreases and the heat rejection increases.

Heat rejection is carried out by radiating the heat through the surface of the skin, by conduction, by evaporation of perspiration from the surface of the body, by heating the expired air, etc. The percentage of heat lost due to radiation is approximately 40-45% . If a person finds himself in an excessively high ambient temperature but in his immediate vicinity there are objects which are at lower temperature, then the fraction of radiated heat increases in relation to the total heat loss. Similar phenomena may be observed during high altitude flights in aircraft, the cabin walls of which do not have any thermal insulation. In such cases the pilot may perceive a sensation of cold even when the air temperature in the cabin is +15 to +16° C. /99

In conditions in which the temperature of the ambient air and adjacent objects is equal to the body temperature or exceeds it, the rejection of heat by radiation ceases.

The human body loses its heat by means of conduction when the temperature of the ambient air is lower than the body temperature. It is obvious that the lower the temperature of the ambient air, the greater will be the amount of conduction heat loss of the person. A large fraction of the heat loss is by evaporation of the perspiration from the surface of the skin, and evaporation of the moisture in the lungs during respiration. The quantity of these heat losses depends essentially on the degree of humidity of the ambient air and the velocity of its motion around the body. When the air temperature and the temperature of objects surrounding the person is $+37^{\circ}$ C and above, the only source of heat loss is evaporation of the perspiration.

Due to the perfection of the mechanisms controlling the temperature, a human being may survive and retain his working capacity even with very considerable variations of air temperature. According to data derived from observations, a human being may remain for 15 minutes in dry air at a temperature of $+80^{\circ}$ C and, at the other extreme, in warm clothing the human being may withstand unusually low temperatures (down to -60° C and lower). High moisture content of the air increases considerably its heat conductivity and its heat capacity (enthalpy) and, for that reason, it sharply reduces the limits of temperature endurance.

Although the human body may withstand considerable variations in temperaure of the ambient medium, this does not mean that these variations in temperature have no effect on the person's condition and his capabilities. Too low, as well as too high temperatures, lower considerably the working capability and increase fatigue. The most satisfactory temperature for the human body is within the range +18 to $+20^{\circ}$ C; at this temperature, with an air humidity of 50% and a low air velocity, a human being does not feel either cold or heat. Such conditions are the most suitable for human beings. They enhance increased stability of the organism to the action of all the factors of the external medium and, particularly, they increase the resistance of the body to the effects of lowered barometric pressure, accelerations etc.

In connection with the above, retention in the aircraft cabins of a temperature within the range of +18 to $+20^{\circ}$ C is one of the most important requirements from the health point of view. /100

However, the maintenance of such temperatures in the cabins of modern aircraft involves considerable difficulties, since the temperature encountered there tends to vary within wide limits. Very often on the ground, or at relatively low altitudes, the walls of the aircraft cabin are strongly overheated as a result of solar radiations, particularly during very hot weather. In addition, heating is also caused by the air from the compressors. As a result, the temperature inside the cabin may reach $+50^{0}$ C and sometimes even more.

Absence of thermal insulation of the walls of the cabin in certain fighter and other type planes, increases the radiation heat losses of the body. Pilots experience a sensation of freezing even if the air temperature inside the cabin is sufficiently high.

Considerable differences in temperature between the upper and the lower zones of the cabin have a particularly unfavorable effect on the working capability and the health of the air crew.

Suitable temperature conditions in the cabins of modern fighters and bombers which fulfill health requirements are ensured by providing thermal insulation of the cabin walls and a proper distribution of the hot air feed from the compressors.

Certain types of aircraft use special heating devices and systems in order to secure normal temperature conditions.

Although heating of the cabin plays an important role in fulfilling health conditions in the aircraft, cooling of the cabin during hot weather at low altitudes is of equal importance. For this purpose atmospheric air can be used to ventilate the cabin. However, such ventilation may only be carried out up to an altitude of 2000 m, that is up to the moment of pressurization of the cabin. For that reason, aircraft with pressurized cabins employ turbo-coolers for cooling the air. The use of turbo-coolers, heating devices and temperature control systems permits maintaining the temperature of the cabin air at any altitude within the limits dictated by health requirements.

However, it should be noted that in the southern regions an aircraft becomes very much overheated during its stay on the ground and pilots in the cabins are very often exposed to high temperatures. Therefore, air- /101 fields should be equipped with the necessary means to protect aircraft from direct solar rays.

The chemical composition of the air in the cabin may also have an effect on the health and working capability of the air crew. For that reason, prevention of contamination of the cabin air is of great importance. The cabin air may become contaminated by exhaust gases, gunpowder gases, pyrolysis products of mineral lubricants, vapors of gasoline and kerosene. The most noxious for the human organism are the exhaust gases. These contain: carbon monoxide (CO) - 10.8%, oxygen (O_2) - 1.2%, methane

(CH_4) - 0.7%, nitrogen (N_2) - 83.8%, etc. The concentration of the above

gases may vary within considerable limits according to the fuel, engine condition, flight altitude, etc. The exhaust gases may penetrate into the cabin and contaminate the air. Of all the components of the exhaust gases, the most dangerous is carbon monoxide; the toxicity of carbon monoxide is extremely high. A concentration of carbon monoxide in the inspired air of 0.2% is lethal if such air is used for respiration for 5 hours, and the respiration of air containing 3-5% carbon monoxide may lead to death if such air is breathed for a few seconds. Even if the air contains carbon monoxide in a fraction of a percent, symptoms of poisoning appear after a certain length of stay in such an atmosphere.

The effect of carbon monoxide is primarily concentrated on the central nervous system. Carbon monoxide poisoning may be slight or acute. Slight poisoning is characterized by headaches, vertigo and general weakness. Sometimes nausea and vomiting occur. In acute cases of poisoning there may be loss of consciousness and convulsions. The nature of the action of carbon monoxide lies in that it combines with the hemoglobin of the blood. As a result of this chemical reaction, a stable chemical compound - carboxyhemoglobin - is formed and hemoglobin loses its capability of combining oxygen and supplying it to the tissues. Consequently, during carbon monoxide poisoning the transport of oxygen by means of blood to the tissues is disturbed, which causes oxygen starvation of the tissues. It should be noted that the chemical affinity of hemoglobin towards carbon monoxide is 200 times greater than towards oxygen. For that reason, even with an extremely small concentration of carbon monoxide in the inspired /102
air, the hemoglobin will combine to a considerable extent with the carbon monoxide.

A stay in an atmosphere with a lowered partial pressure of oxygen and presence in the inspired air of carbon monoxide contaminants increases very considerably oxygen starvation; the working capability of a human being is impaired to an even greater extent. For that reason it is necessary to take every possible measure in order to eliminate the possibility of carbon monoxide penetrating into the cabin of the aircraft or, in extreme cases, to make sure that the concentration of carbon monoxide does not exceed the permissible limit, viz. 0.02 mg/liter. Thereby, carrying out the work specified by the rules on the engines and their screening at the right time is of great importance.

When parts of the aircraft engine become hot, the mineral lubricants start to decompose and a number of gaseous substances form which may have untoward effects on the human organism. The most important of these is acrolein, which causes irritation of the mucous membrane, of the upper respiratory passages and of the eyes.

In addition to acrolein, formaldehyde and non-saturated hydrocarbons may also form during the decomposition of mineral lubricants; these exhibit general as well as local irritating effects.

The maximum permissible concentration of acrolein in the air of an aircraft cabin is 0.002 mg/liter, that of formaldehyde 0.005 mg/liter. In addition to the above toxic substances the vapors of gasoline and kerosene may also enter the aircraft cabin. The maximum permissible concentration for these vapors is considered to be 0.05mg/liter of air.

Gunpowder gases should not penetrate into the cabin of the aircraft. In addition to carbon monoxide, they also contain oxides of nitrogen. The accepted maximum permissible concentration of nitrogen oxides in the air is 0.005 kg per one liter of air. (Abstractor's note: This is obviously wrong; it should read 0.005 mg per one liter of air. The quantity stated is highly lethal.)

Observation of modern aircraft equipped with pressurized cabins has shown that, as a rule, the concentration of carbon monoxide and other toxic gaseous products in the air of the cabin is considerably lower than the permissible standards. However, study of the same MiG-15 type aircraft after prolonged operation has shown that sometimes the concentration of carbon monoxide and other toxic substances exceeds the permissible levels. Taking this into consideration, systematic chemical analysis should be carried out in the squadrons to assess the composition of the air in aircraft cabins under all flight conditions.

In order to prevent contamination of the cabin air with noxious gases, continuous ventilation of the cabin is provided, which secures a normal chemical composition and physical properties of the air, favorable for the life functions and work of the pilot. As a rule, air conditioning is applied. In any type of ventilation system the velocity of air flow should not exceed 0.5-1 m/sec. /103

Pressurized Cabins

Pressurized cabins in aircraft differ from ordinary cabins in that the inside pressure is greater than the ambient atmospheric pressure. Due to this fact, it is possible to use in pressurized cabins the standard oxygen breathing apparatus and thus avoid the possibility of decompression disorders. Furthermore, pressurized cabins secure more suitable temperature conditions.

From the point of view of the physiological requirements, maintenance in the cabin of a normal atmospheric pressure would be the most suitable. However, accomplishment of these conditions is connected with a number of difficulties. Inevitably, a significant increase of the pressure in the cabin over the ambient atmospheric pressure imposes the necessity to increase the strength of the cabin, which leads to an increase in weight. This is particularly unfavorable with high-altitude aircraft. In addition, during the decompression of the cabin at a high altitude there is the danger of injury to the lung tissues and the intestines of the air crew and the passengers, due to the pressure fall. Taking these factors into consideration, the pressure in the cabin is kept within certain limits in accordance with the altitude.

In pressurized cabins, maintenance of the necessary partial pressure of oxygen can be achieved in the following ways:

- by maintaining a sufficiently high absolute pressure of air in the cabin;
- by increasing the percentage content of oxygen in the air of the cabin;
- by simultaneous application of the above two methods.

According to their characteristics, pressurized cabins are divided into the following three types:

1) pressurized cabins of the ventilation type with supercharge; /104
2) pressurized cabins of the regenerative type;
3) pressurized cabins of the mixed type.

Pressurized Cabins of the Ventilation Type with Supercharge

Modern aircraft have pressurized cabins of the ventilation type with supercharge. In such cabins the pressure and ventilation are produced with the help of the air coming from the compressors or from the cabin superchargers. The atmospheric air is forced into the cabin. If the supercharging and the ventilation of the cabin are carried out with the air coming from the compressor of the engine, the air, on leaving the supercharger, may contain oil in the form of a fine oil mist, kerosene in a suspended state, oil decomposition products (acrolein and other aldehydes) and carbon monoxide.

The formation in the air of these contaminants is made easier by the high velocities of the compressor impeller, as a result of which oil from the bearings is atomized into extremely fine droplets. In addition, air sucked into the compressor may also contain some kerosene from the kerosene-feed system, if the latter is not fully hermetic. As a result of the high air temperature at the end of the compression, processes leading to the decomposition of oils and kerosene take place which produce acroleins and aldehydes.

In order to prevent penetration of the noxious admixtures into the cabin, the inlet ducts are equipped with special filters.

If the total pressure in the cabin is sufficiently large, it is possible to use efficiently oxygen apparatus. 110 mm Hg is considered the lower limit of the partial pressure of oxygen in the inspired air, which corresponds to the conditions of flight at an altitude of 3,000 m without auxiliary oxygen feed.

With a partial pressure of oxygen in the inspired air of 110-160 mm Hg, the partial pressure of oxygen in the alveolar air is maintained in the range 65-100 mm Hg.

The magnitude of the air feed into the cabin depends on its volume.

On average, the volume of air in the cabin is exchanged ten times per hour.

The magnitude of the excess pressure in relation to the atmospheric /105
pressure in cabins of the ventilation type is determined mainly by the flight duration. The longer a human being stays at a high altitude, the more noticeable will be the effect of the rarefied atmosphere and the more will his working capacity be lowered. Taking this into consideration, it is necessary to maintain a higher pressure in the pressurized cabins of aircraft designed for prolonged flights than in cabins of aircraft with short flight durations.

When using oxygen apparatus, the minimum permissible absolute pressure in pressurized cabins should be not less than 308 mm Hg, which corresponds to the altitude of 7,000 m. At lower pressures in the cabin there is danger of decompression sickness.

In aircraft designed for flights in excess of two hours, the programmed pressure conditions in the cabin are approximately as follows: at altitudes up to 2,000 m the pressure corresponds to the pressure of the external atmospheric air; at altitudes from 2,000 to 7,000 m it is of the order of 596 mm Hg, i. e. a pressure corresponding to the atmospheric pressure at an altitude of 2000 m. At greater altitudes, a constant excess pressure of 0.4 kg/cm^2 (294 mm Hg) is maintained. Aircraft designed for flights up to two hours have pressure in the cabin at altitudes up to 2,000 m corresponding to atmospheric pressure; and at altitudes from 2,000 to 6,000 m a constant pressure is maintained of the order of 596 mm Hg, which corresponds to the pressure at an altitude of 2000 m. At higher altitudes the constant excess pressure of 0.3 kg/cm^2 is maintained, i. e. approximately 220 mm Hg.

When the "height" in the cabin reaches 3,000 m, all the crew members should switch on their oxygen supply; in the case of fighter planes the oxygen supply is started from the ground; for this purpose oxygen apparatus of the "artificial lung" type is used.

Pressurized Cabins of the Regenerative Type

By regenerative pressurized cabins are understood cabins with a closed cycle of air circulation, that is, air which is contained in the cabin from the beginning of pressurization; the air is not replaced from outside or is topped up with very small quantities only. Consequently, the main characteristic of regenerative pressurized cabins will be the fact that the internal air will be fully isolated from the external atmosphere and will not depend on the composition and state of the outside air.

Pressurized cabins of the regenerative type may find applications in aircraft in which there is no source of supercharge, and also in aircraft with high ceiling, where the use of compressors and superchargers for supercharging the cabin becomes technically difficult or impossible in view of the extreme rarefaction of the air. /106

In the regenerative types of cabins, special absorbers are installed for the absorption of the water vapor (each member of the crew exhales in one hour into the ambient atmosphere of the cabin 50-60 grams of moisture and 30-60 liters per hour of carbon dioxide). In these cabins there is no need for special arrangements for supercharging and ventilation. The air which has escaped from the cabin is supplemented by releasing into the cabin compressed air which is carried aboard the aircraft in cylinders. In addition to this, the loss of oxygen is also supplemented from compressed-oxygen cylinders. This is the way in which the reconstitution of the original properties of the air is carried out.

The main purpose of this regeneration consists in retaining the contents of oxygen, carbon dioxide and water vapor in the cabin air within the limit of the physiological and health requirements.

In order to ensure the air circulation through the regenerative charges of the absorbers, electrically driven fans or injectors are used.

Pressurized cabins of the regenerative type must comply with the following physiological and hygienic requirements:

1) the partial pressure of oxygen in the cabin should be in the range 125-160 mm Hg; in order to limit the danger of fire the content of oxygen in the air should not exceed 50% ;

2) the partial pressure of carbon dioxide should not exceed 15 mm Hg;

3) the relative humidity of the air should not exceed 80 %

The quantity of oxygen required by one member of the crew is assessed at 30 liters per hour. However, in view of the escape of air from the cabin it is necessary to correct the value of the required quantity of oxygen by taking into consideration the extent of the escape.

Pressurized Cabins of the Mixed Type

The difference between these and cabins of the regenerative type is that in these cabins the carbon dioxide and moisture from the air of the cabin is not removed by chemical absorption but by ventilating the cabin /107 with the help of compressed air or oxygen from the cylinders carried in the aircraft. The air or oxygen is injected into the cabin and the excess escapes through the valve controller into the atmosphere. Together with the rejected air the excess of carbon dioxide and water vapor is also rejected. The advantage of this type of cabin over the regenerative type is that there is no need to fit regenerative charges to the absorber. However, such cabins have not so far found application since, in order to utilize them, it is necessary to carry in the aircraft large quantities of oxygen and air.

High Altitude Pressure Suits

A high altitude pressure suit is a special suit for individual use. At the present time the high altitude pressure suit is recommended as a safety device for protecting the members of the crew during decompression of the aircraft cabin at altitudes in excess of 12,000 m, and also as a means of enabling the flight to be prolonged at any altitude for the whole time after the collapse of the pressurization system of the aircraft cabin.

The high altitude pressure suit comprises a hermetic suit made of suitable material with a detachable transparent helmet, provided with special valves which permit maintenance under the surface of the suit of a pre-determined excess air pressure.

The high altitude pressure suits are divided into ventilational and regenerative suits.

Suits of the ventilation type are used in the more dense layers of the atmosphere, where it is still possible to compress the atmospheric air for the purpose of supercharging and ventilation.

Suits of the regenerative type will be more desirable in the case of flights at altitudes ranging from a few tens of kilometers, that is very low pressure, and in conditions of complete vacuum, since their work does not depend on the ambient atmosphere.

In suits of the regenerative type, carbon dioxide and moisture exhaled during respiration are eliminated by means of absorption in special chemical absorbers.

At present in the field of aviation, chiefly pressure suits of the ventilation type are being developed. The ventilation suit outfit includes a hermetically sealed overall, a hermetic helmet, pressure controller, special oxygen instrument and a unit for supplying conditioned /108
air. The helmet is connected hermetically to the overall of the suit. The suit helmet may be either detachable or non-detachable. For convenience, the front part of the helmet can be thrown back. The pressure suit is connected by means of a special tube with the supercharging system of the pressurized cabin. If necessary, it is possible to produce in the suit an excess pressure of the order of 0.15-0.20 atmosphere with respect to the ambient atmosphere. The excess pressure in the suit is maintained at such a level that the required partial pressure of oxygen is secured for the purpose of respiration.

The control valve in the pressure suit not only maintains the necessary excess pressure but also effects its ventilation. The oxygen is supplied from the aircraft oxygen apparatus or it is fed directly into the helmet of the suit. In this way all the conditions are produced which are necessary for a human being to remain at high altitudes and still retain his working capacity.

During the flight in the pressurized cabin the pilot wears his pressure suit (underneath his flying suit) with the helmet open. The suit is ventilated by means of air from the supercharger of the cabin and from the source of ventilation of the pressurized cabin. The oxygen feed is derived from the aircraft oxygen instrument, as is done during ordinary flight without a pressure suit.

If the pressurization of the cabin fails at high altitudes, the helmet is closed and the pressure in the cabin rapidly equalized with the pressure in the ambient atmosphere. In this case the necessary conditions of excess pressure in the suit are quickly produced by the action of the supercharging system. As before, the oxygen supply is taken from the aircraft oxygen apparatus.

On escaping from the aircraft the pressure suit is automatically disconnected from the supply hoses and connected to the parachute oxygen apparatus which supplies the pilot during his fall towards the ground with oxygen down to a certain altitude. The supercharging of the pressure suit during this time is carried out by means of the oxygen fed from the parachute oxygen apparatus.

The suit is not only useful in saving the lives of the crew but also makes it possible to prolong the flight at a given altitude should the supercharging system fail. In addition to all that has been said /109
before, the main merits of the high altitude pressure suit are that it is much easier to endure pressure fall and the effect of the high velocity air stream during ejection at flight velocities up to 1200 km/hour.

Modern high-altitude pressure suits still suffer from a number of imperfections. The most important of these are: lack of comfort in wearing the suit up to the moment of its intended use; it is awkward to put on; it reduces the wearer's freedom of movement during flight; the helmet tends to become steamed up by perspiration in the case of insufficient ventilation; relatively short service life of the suit. Furthermore, the body is likely to overheat when the suit is worn.

However, in spite of the above disadvantages, the merits of the pressure suit should not be underestimated; it is obvious that pressure suits will be widely used in high-altitude aviation.

The physiological and hygienic requirements to be met by high-altitude pressure suits can be summarized as follows:

- a partial pressure of oxygen, not less than 110 mm Hg, should be secured in a pressure suit;
- the sub-suit space should be sufficiently ventilated in order to remove water vapor and carbon dioxide;
- the permissible level of carbon dioxide in the air of the suit is 3% and the relative humidity should not exceed 85%;
- the suit should provide protection against cold for several hours;
- the material of the suit should be soft, pliable and nonflammable;
- the suit should not hinder the respiration, blood circulation, nor limit movement;
- the suit should not cause overheating of the body.

CHAPTER VI /110

PHYSIOLOGICAL AND HYGIENIC BASES OF OXYGEN BREATHING INSTALLATIONS

During high altitude flights, there is a fall in the general atmospheric pressure and a decrease in the partial pressure of oxygen in the inspired air. In order to create normal living conditions for the human organism, it is therefore necessary to add oxygen to the inspired air in such proportions that its partial pressure in the alveolar air of the lungs should approach the quantities existing at ground level (100-105 mm Hg) or that it should be no lower than that existing at an altitude of 2,500-3,000 m.

These requirements are satisfied by aircraft oxygen installations which are provided in all military aircraft.

On the basis of the physiological and hygienic requirements, the present day aviation oxygen breathing installations can be sub-divided into the following three types:

1. Oxygen apparatus with continuous flow, i.e. instruments in which the oxygen feed under the mask is continuous, during the period of inspiration as well as during the period of expiration.

2. Oxygen apparatus with periodic supply, of the "artificial lung" type, i.e. apparatus in which the oxygen under the mask is fed-in only during inspiration, during expiration the oxygen supply is cut off. The supply rate of oxygen under the mask is controlled by the respiration of the wearer.

3. Oxygen apparatus of the artificial lung type, with the oxygen feed under excess pressure. Apparatus of this type work as ordinary artificial /111 lungs up to the altitude of 12,000 m, and from the altitude of 12,000 m onwards they feed oxygen into the respiratory passages of the wearer, under a pressure which exceeds that of the ambient atmosphere.

The existing aviation oxygen installations can also be classified into three groups according to their intended use:

1. Stationary oxygen apparatus carried aboard the aircraft, intended for supplying oxygen to crew members at their working stations; these are installed in the cabin of the aircraft, on the basis of one apparatus for each member of the crew.

2. Portable oxygen apparatus aboard the aircraft, designed for supplying the crew members with oxygen while they are moving about in the aircraft.

3. Parachute oxygen apparatus, intended for supplying oxygen to the crew members during descent by parachute from high altitudes, in the case of accident in the air followed by abandoning the aircraft.

The main requirements of the oxygen apparatus of all types may be summarized as follows:

- High efficiency of oxygen supply;
- economy of oxygen consumption;
- the altitude at which it can be applied should be as high as possible;
- the resistance to inspiration should be small;
- simplicity of operation.

Oxygen

Oxygen - a transparent, colorless gas without odor or taste, has high chemical activity.

Oxygen is somewhat heavier than air: 1 m^3 of gaseous oxygen at a temperature of 0° C and a pressure of 760 mm Hg weighs 1.428 kg, while 1 m^3 of air weighs 1.293 kg. Whatever the pressure applied, gaseous oxygen cannot be liquefied at room temperature. Its liquefaction can be achieved at a temperature of -118.8° C and a pressure of 51.53 atmosphere. This temperature and pressure are known as critical. At normal atmospheric pressure, that is 760 mm Hg, the liquefaction of oxygen can be achieved at a temperature of -182.95° C. Liquid oxygen is a mobile, transparent liquid of bluish color. The specific gravity of liquid oxygen is 1.118, that is /112
1 liter of liquid oxygen weighs 1.146 kg.

By evaporating 1 liter of liquid oxygen at 0° C and normal atmospheric pressure, 800 liters of gaseous oxygen are obtained.

Oxygen is one of the most widely spread elements of our planet. Oxygen accounts for 50% of the total earth matter content. The air contains approximately 21% of oxygen, and water up to 88%. In a free state, oxygen is found only in the atmospheric air. At present, oxygen is used in industry, aviation, and in medicine.

In the field of aviation, in order to make high altitude flights possible, medical oxygen is used; this should contain 98% of oxygen and not more than 2% of inert gases.

As is well known, the process of combustion is very vigorous in an oxygen atmosphere. In view of this fact, it is frequently stated that respiration with pure oxygen may lead to more intensive oxidative processes in the cells and tissues of the organism, and in this way lead to premature "burning" of their substance. In other words, respiration with pure oxygen may be harmful to the organism.

These views are without foundation. Numerous studies carried out in this field during the last decade in the Soviet Union and abroad have shown that breathing with pure oxygen under a pressure exceeding the atmospheric pressure does not lead to an increase, but to a pronounced reduction in the oxidative processes within the cells and tissues.

Toxic phenomena in the case of human beings may only appear if the subject is in an atmosphere of pure oxygen under a pressure in excess of two (2) atmospheres for a period of some hours. For instance, toxic symptoms such as convulsions may follow, on an average, after a three hours' stay in a chamber filled with pure oxygen at a pressure of 3 atmospheres. When the oxygen pressure rises to 4 atmospheres the toxic symptoms appear within 40 to 45 minutes

Observations have shown that the greater the oxygen pressure, the quicker and stronger will be the symptoms of poisoning.

When pure oxygen under a pressure of 1 atmosphere is used for /113
breathing for a number of hours every day (even for long periods of time) no untoward symptoms are observed.

It is obvious that in aviation practice there is no danger of toxic effects if during their flight the aircrew do not use for breathing oxygen under a pressure greater than 1 atmosphere. This has been sufficiently verified by numerous experiments in pressure chambers and by long flight practice with the use of oxygen breathing apparatus.

For flights, medical oxygen is supplied as a rule from 40-liter transport cylinders under a pressure of 150 atmospheres.

Cylinders of 4 to 12 liter capacity are fitted in aircraft, and the most frequently used working pressure is 150 atmospheres.

The quantity of oxygen in a cylinder is measured in liters, corrected to the pressure of 760 mm Hg and a temperature of +15° C.

In order to determine the quantity of oxygen in a cylinder, one should multiply the volume of the cylinder by the pressure of the oxygen in it. For instance, in the 8-liter cylinder with a pressure of 150 atmospheres at +15° C, the quantity of oxygen will be equal to 8 x 150 = 1,200 liters.

However, at high altitudes under low temperature conditions, the pressure of oxygen in the cylinder will decrease by 1/273 per each degree Centrigrade. Let us assume that at the flight altitude the temperature is -50° C. The pressure in the cylinder will decrease by 65/273 of the original quantity and will be equal to

$$150 - \frac{65 \times 150}{273} = 114.3$$

The quantity of oxygen will decrease to 114 x 8 = 912 liters.

Consequently, as the temperature decreases with altitude, the reserve of oxygen also decreases.

It should be borne in mind that if the compressed gaseous oxygen comes into contact with lubricants and greases there is a very rapid process of self-ignition; the reaction during the combustion is of an explosive character. Thus, in the interests of safety, when using any oxygen equipment under high pressure, it is necessary to check very carefully that the oxygen does not come into contact with lubricants, easily inflammable fuels and other substances. Equally, precautions must be taken when dealing with liquid oxygen. Liquid oxygen coming into contact /114 with skin causes burns.

Oxygen Apparatus with Continuous Supply of Oxygen

Oxygen apparatus with continuous supply of oxygen under the mask is used comparatively seldom; its main application is in training and passenger aircraft intended for flights in the altitude range from 10,000 - 12,000 m, and also as a rescue medium (parachute type oxygen apparatus). Apparatus of this type may be either for individual or collective use. Oxygen from the oxygen apparatus is fed under the mask of the open type in a uniform continuous stream under a pressure which exceeds somewhat the pressure of the ambient atmosphere (Figure 15).

The amount of oxygen feed in this type of apparatus increases with altitude and is controlled automatically by means of a special aneroid capsule - the altitude controller. Oxygen apparatus of the continuous feed type usually employs the so-called open masks or masks with supplementary bags which do not have the respiratory valve mechanism (Figure 16). These masks have a sufficiently wide intake (inspiring) opening which /115 ensures free communication of the space under the mask with the atmospheric air. Due to this opening, breathing continues without any perceptible resistance. During the inspiration through the intake opening, the atmospheric air passes freely and mixes with the oxygen fed under the mask from the apparatus. In this way, the pilot breathes a mixture of oxygen and atmospheric air and not pure oxygen during high altitude flights with oxygen apparatus of the continuous feed type. The content of oxygen in this gaseous mixture will depend not only on the quantity of oxygen fed under the mask but also on the depth and frequency of respiration, i.e. on the amount of lung ventilation. It is fully understood that the gaseous mixture which forms will be the poorer in

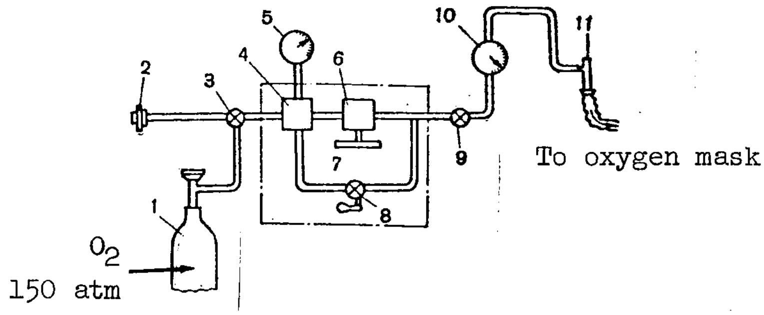

Figure 15. Diagram of the Oxygen Apparatus with Continuous Oxygen Supply.

1 - oxygen cylinder; 2 - charging connector; 3 - main valve; 4 - high-pressure reductor; 5 - manometer; 6 - low-pressure reductor; 7 - altitude controller; 8 - cock for the emergency supply of oxygen; 9 - valve of the apparatus; 10 - consumption indicator; 11 - mask connector.

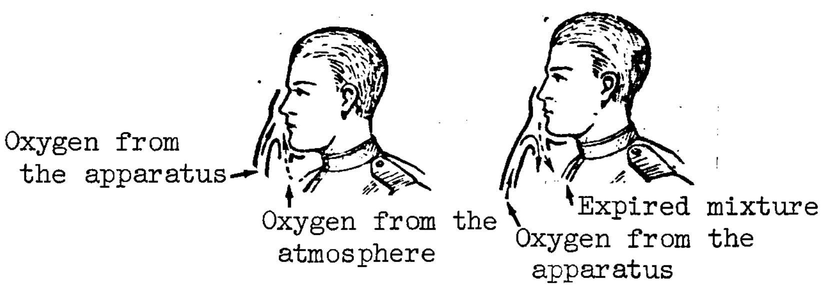

Figure 16. Diagram of the Open Type Oxygen Mask.

oxygen the greater the lung ventilation. Usually, for a person at rest and with normal respiration a small quantity of atmospheric air is added to the oxygen fed from the apparatus. However, in the case of physical exertion, which is accompanied by an increase in the depth and frequency of respiration (increase of lung ventilation), the oxygen becomes diluted with larger quantities of air so that the gaseous mixture will contain less and less oxygen until finally a situation will occur when there is not enough oxygen to ensure the normal supply required by the human body. It should be borne in mind that oxygen supplied by the apparatus in the form of a continuous stream is only being used during the time of inspiration, while during expiration it escapes freely into the atmosphere through the expiring opening of the mask and thus approximately 50% of oxygen is wasted.

Present day oxygen apparatus of the continuous feed type is calculated for a lung ventilation ranging from 7 - 30 liters/min. /116 Depending on the flight altitude the quantity of oxygen supply necessary per one person will vary; it will range from 1.5 liters/min at an altitude of 2,000 m, to 6.5 liters/min at an altitude of 10,000 m. In view of these features, oxygen apparatus with continuous supply ensures the necessary partial oxygen pressures in the inspired air and enables a good working capability of the crew to be retained only up to an altitude of 10,000 m, provided there is no physical exertion and the lung ventilation does not exceed 30 liters/min. The apparatus is equipped with a manual controller.

Some oxygen masks have a supplementary capacity (rubber bag), communicating with the space under the mask. Due to the presence of such a capacity, the consumption of oxygen is more economical. Furthermore, during the inspiration from the bag into the respiratory passages a gaseous mixture enters which has a higher percentage of oxygen. Consequently, the masks with supplementary capacities enable feeding a better supply of oxygen to the human body than masks without a supplementary capacity.

The masks of the oxygen apparatus should adhere tightly to the face, otherwise infiltration of the external air will occur which may lower considerably the positive effect of the supplementary capacity. For that reason, each pilot should carefully select and adjust the mask to his face. At the bottom of the bag there is an opening which prevents the accumulation of the moisture formed as a result of the condensation of water vapor.

For reasons of hygiene, after each use the mask should be wiped with alcohol.

Oxygen apparatus with continuous oxygen feed has its advantages and disadvantages.

The advantages of such oxygen apparatus are:

- low resistance to respiration as a result of continuous oxygen supply to the mask;
- convenience of use owing to the simple design of the apparatus, small dimensions of the mask and hose;
- insignificant changes in the composition of the inspired mixture when the mask does not adhere tightly to the face.

The disadvantages are:

- non-productive loss of oxygen during the expiration;
- a lower altitude ceiling (10,000 m) as compared to oxygen apparatus equipped with hermetically sealed masks.

The Parachute Oxygen Apparatus /117

In practice, during flight at high altitudes, emergency situations may occasionally arise in which the crew has to abandon the aircraft and descend by parachute. The abandonment of the aircraft may take place in the most unpredicted conditions and at various altitudes. In such cases, when the aircraft is abandoned at altitudes in excess of 6,000 to 8,000 m, it is necessary to use a special type of portable oxygen apparatus (the so-called parachute oxygen apparatus) in order to protect the lives of the members of the crew.

According to the above, during flights on military aircraft, each member of the crew is usually supplied with the cabin and parachute oxygen apparatus.

The parachute oxygen apparatus serves to secure the oxygen supply for the members of the crew from the moment they abandon the aircraft up to their descent into the safe zone. It also provides the members of the crew with oxygen in case of failure of the cabin oxygen apparatus during high altitude flight, which would allow them to descend to about 4,000 m and lower. In that case, the pilot should consider the amount of the oxygen supply in the parachute oxygen apparatus, i.e. he and his crew should descend to an altitude of approximately 4,000 m within 13-15 minutes from the commencement of using this apparatus.

The modern parachute oxygen apparatus is used in combination with all the stationary cabin type of oxygen apparatus of the "artificial lung" action with the compensating apparel and the hermetic masks.

The parachute oxygen apparatus belongs to the group of the "face apparatus" used with "continuous feed of oxygen".

From the moment a member of the crew abandons the aircraft the switching over from the oxygen supply derived from the cabin oxygen apparatus to the parachute apparatus takes place automatically by the action of an automatic switch.

The parachute oxygen apparatus is very simple in construction and comfortable in use. The apparatus is easily packed since its dimensions are very small. It is packed into the parachute bag (or container).

The complete unit of the parachute oxygen apparatus comprises:

- the apparatus proper, consisting of a battery of small oxygen cylinders connected in series, switch with a locking-off valve, oxygen manometer, capillary tube, charging connector with a non-return valve /118
and a screwed blank;

- two oxygen hoses: a hose leading to the mask and a hose with special attachment lock to the stationary apparatus and to the switch of the parachute apparatus;
- oxygen mask.

The parachute oxygen apparatus does not have an aggregate of reductors, an oxygen indicator, or an oxygen flowmeter. There is no constant standard for oxygen feed rate of parachute oxygen apparatus. Oxygen is fed continuously and the quantity supplied in one minute depends on the pressure in the small cylinders.

If the capacity of the small cylinders is 0.865 liters and the pressure is 150 atmospheres, the reserve of oxygen in the apparatus is 129.7 liters. If the original pressure in the small cylinders is 150 atmospheres, the rate of oxygen flow during the first minute after switching on the apparatus exceeds 16 liters/min, and 10 minutes after being switched on the flow is at a rate of 3.6 liters/min, i.e. almost five times smaller than the initial rate.

A supplementary small cylinder, included in the unit, is intended for quickly filling the pneumatic system of the compensating apparel with oxygen after switching on the apparatus.

Oxygen Apparatus with Periodic Supply of Oxygen of the "Artifical Lung" Type

Within the last few years oxygen apparatus with periodic oxygen supply of the "artificial lung" type has become very popular in aviation. This apparatus is called "automatic" or "artificial lungs" because it is activated by the respiration of the human being. Oxygen apparatus of the artificial lung type is used only in combination with the special hermetic masks equipped with valves. A diagram of such apparatus is shown in Figure 17. Each inspiration into the respiratory passages of oxygen, or its mixture with atmospheric air, is fed under a pressure which does not exceed the pressure of the ambient atmosphere. The expiration into the external atmosphere is through the expiratory valve of the mask, which opens during the expiration and remains closed during the inspiration. In contrast to the continuous oxygen feed apparatus, which is equipped with masks of the open type, the percentage composition of oxygen in the gaseous mixture fed from apparatus of /119
the automatic lung type does not depend on the depth and frequency of respiration. It is maintained automatically within the required limits in accordance with the flight altitude by increasing or decreasing the rate of intake of the atmospheric air. With increasing altitude the rate of air intake decreases and the percentage content of oxygen in the inspired gaseous mixture increases continuously. At an altitude of 9,000 to 10,000 m, the intake of air from the ambient atmosphere into the apparatus ceases and the apparatus feeds pure oxygen into the respiratory

passages. The quantity of the gaseous mixture is determined by the depth and frequency of the respiration (lung ventilation) which, in its turn, depends on the physical exertion of the person. However, when oxygen apparatus of the artificial lung type is used, the consumption of oxygen exceeds the required quantity. Oxygen apparatus with "backing" (which create under the mask a slight excess pressure) with lung ventilation of 15 liters/min at an altitude of 8,000 m consume about 5-6 liters of oxygen per minute instead of 3 liters/min required at this altitude.

The mask of the oxygen apparatus should fit hermetically to the face. If the mask does not adhere tightly to the face, the small rarefaction under the mask created during the time of inspiration may cause an infiltration of the atmospheric air at the edges of the mask. At altitudes of 6,000 to 10,000 m, this may produce oxygen starvation.

If in the contemporary oxygen apparatus of the artificial lung type, the mask is damaged, or does not adhere tightly to the face, the oxygen is fed not only during the time of inspiration but also during the time of expiration. The continuous stream of oxygen creates "backing" under the mask and in this way the possibility of the air intake through the edges of the mask is eliminated. However, this causes an increased consumption of oxygen. /120

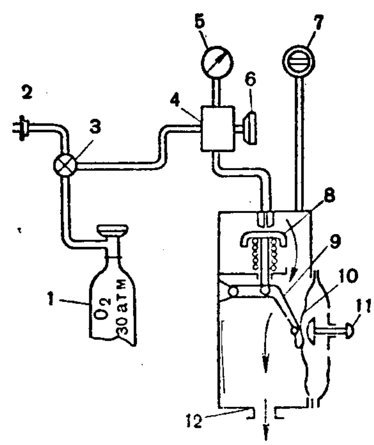

Figure 17. Diagram of Oxygen Equipment Employing Apparatus with Periodic Oxygen Supply:

1 - oxygen cylinder; 2 - charging connector; 3 - cabin valve; 4 - reductor; 5 - manometer; 6 - valve of the apparatus; 7 - oxygen indicator; 8 - valve of oxygen apparatus; 9 - lever; 10 - elastic diaphragm; 11 - button (or mechanism); 12 - connector for the hose of the mask.

Up to an altitude of 10,000 m, the artificial lung secures a partial pressure of oxygen in the inspired air equal in magnitude to the partial pressure of oxygen in the atmospheric air at sea level.

It was established experimentally that the partial pressure of oxygen in the alveolar air (using oxygen apparatus of the artificial lung type) at altitudes from 4,000 to 9,000 m is higher than the respective value at ground level (i.e. 100 - 105 mm Hg). At an altitude of 10,000 m the partial pressure of oxygen in the air of the lung alveoli (when using oxygen apparatus of the artificial lung type) becomes equal to the value at ground level.

With further ascent, even respiration with pure oxygen cannot secure the necessary partial pressure of oxygen in the alveolar air and it decreases progressively with altitude. At an altitude of 11,000 m it is still equal to 90 mm Hg and at an altitude of 12,000 m - 70 mm Hg, i.e. is equal to the partial pressure of oxygen during flight at an altitude of 3,000 m without oxygen apparatus. However, even with oxygen apparatus, at an altitude of 12,000 m the general well-being and working capability is always somewhat worse than it is at an altitude of 3,000 m without any supplementary oxygen feed; this is undoubtedly due to the much greater degree of rarefaction of the atmosphere.

At altitudes in excess of 12,000 m oxygen apparatus of the "artificial lung" type cannot secure the necessary partial pressure of oxygen in the inspired air. For that reason they are not suitable for ascent to altitudes in excess of 12,000 m, even for very short periods of time.

Oxygen apparatus with periodic feeding of oxygen has certain advantages and disadvantages.

Its advantages are:

- the economy in the consumption of oxygen;
- greater altitude (12,000 m) at which they can be used as compared with continuous oxygen supply apparatus;
- the possibility of using these as gas-masks, since they are equipped with airtight masks.

Its disadvantages are:

- considerable resistance (up to 4 mm Hg) to inspiration, since for actuating the apparatus the necessary rarefaction has to be produced in it before a portion of oxygen will flow into the mask;
- it is more complicated to use than apparatus of the open type; this /121
apparatus requires more careful manipulation, viz. individual adjustment

of the mask and constant control of its tightness and adhesion, special preliminary training of the flying personnel and development of certain habits in the use of the apparatus.

As was mentioned before, oxygen apparatus of the artificial lung type is applied most widely in aviation due to its advantages over apparatus of the type with continuous oxygen supply.

Oxygen Apparatus of the Artificial Lung Type for Breathing with Oxygen Under the Excess Pressure

At altitudes exceeding 12,000 m, the total atmospheric pressure and the partial pressure of oxygen is so low (total atmospheric pressure at an altitude of 12,000 m equals 145 mm Hg and the partial pressure of oxygen is 30 mm Hg), that even when breathing with pure oxygen, using orthodox instruments of the artificial lung type, it is not possible to create the necessary partial pressure in the inspired and alveolar air of the lungs.

Flights at altitudes in excess of 12,000 m with the orthodox oxygen equipment of the "artificial lungs" type are possible on aircraft equipped with pressurized cabins, inside of which the pressure is higher than the pressure of the ambient atmosphere.

However, in the case of cabin decompression emergencies at altitudes in excess of 12,000 m, the pilot using the ordinary apparatus of the artificial lung type will begin to experience acute oxygen starvation, as a result of which his working capacity will rapidly fall. This may also lead to a loss of consciousness. These phenomena are due to the far too low atmospheric pressure existing at these altitudes, which in turn is responsible for the low partial pressure of oxygen in the inspired air and in the alveolar air. For instance, at an altitude of 13,500 m the partial pressure of oxygen in the alveolar air, when breathing with pure oxygen, is lowered to 40 mm Hg, i.e approximately the magnitude which is encountered when breathing atmospheric air at an altitude of 5,000 m. This very low partial pressure of alveolar oxygen is insufficient for ensuring the required normal saturation of the blood with oxygen and to prevent a drop in the working capacity. In order to improve the supply of the organism with oxygen at altitudes in excess of 12,000 m, it is necessary to increase the pressure of the /122
inspired oxygen supplied by the oxygen apparatus. This is attained by means of oxygen apparatus with increased pressure (Figure 18).

At altitudes in excess of 12,000 m, increased pressure oxygen apparatus feed pure oxygen under the mask at a pressure which exceeds the pressure in the ambient atmosphere.

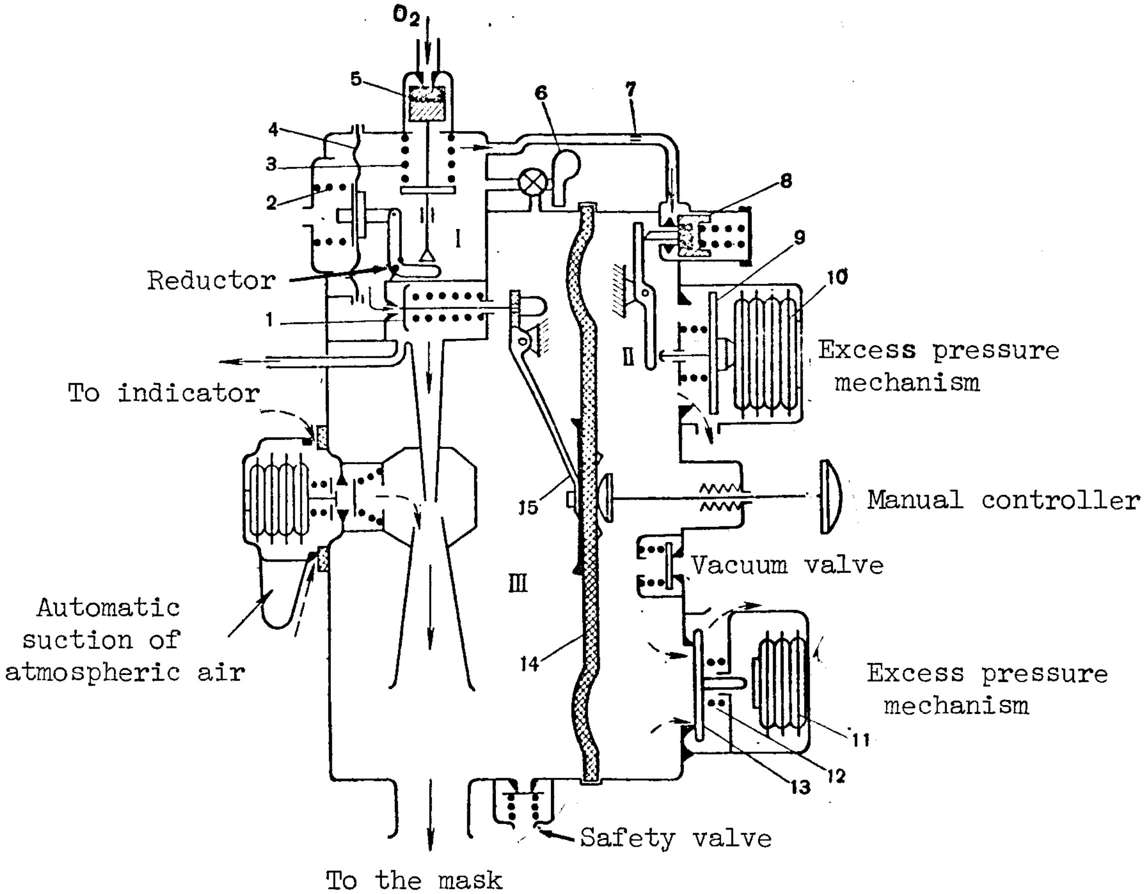

Figure 18. A Diagram of Excess Pressure Oxygen Apparatus.

1 - valve of the artificial lung mechanism; 2 - main spring of the reductor; 3 - auxiliary spring; 4 - reductor diaphragm; 5 - inlet valve; 6 - cock for the emergency supply of oxygen; 7 - nozzle; 8 - valve; 9 - valve; 10 - aneroid; 11 - aneroid; 12 - spring; 13 - valve; 14 - diaphragm; 15 - lever

Due to the excess pressure of the oxygen fed into the respiratory passages, the partial pressure of oxygen in the alveolar air is increased, which in turn increases the saturation of the arterial blood. For instance, when breathing at an altitude of 15,000 m with pure oxygen fed under the mask under an increased pressure equal to 20-25 mm Hg (above the pressure of the ambient atmosphere), the partial oxygen pressure in the alveolar air reaches 40-42 mm Hg. This will secure, for a certain period of time, the retention of satisfactory working capacity at altitudes up to 15,000 m. The mask of the oxygen apparatus with increased pressure (Figure 19) should fit the face /123

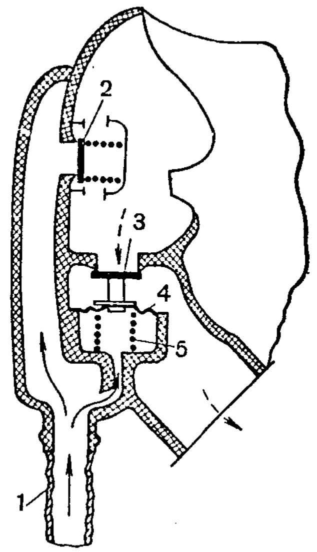

Figure 19. Diagram of the Oxygen Mask Employed in the Excess Pressure Oxygen Apparatus with a Compensating Diaphragm.

1 - crimped hose; 2 - inspiring valve; 3 - expiring valve; 4 - compensating diaphragm; 5 - spring.

absolutely tightly, since the excess oxygen pressure under the mask tends to separate the mask from the face. In the case of a bad fit it is difficult to retain the necessary excess pressure under the mask and to keep the consumption of oxygen to an economic level.

Oxygen apparatus with increased pressure represents an improved version of the ordinary artificial lung type apparatus. During flights in pressurized cabins, apparatus with increased pressure works as ordinary artificial lung type apparatus but, in the case of accident in the pressurization of the cabin at altitudes exceeding 12,000 m, they switch over automatically to the supply of oxygen under increased pressure. The amount of oxygen supply (with lung ventilation of 15 liters/min) varies with altitude from 2 liters/min at an altitude of 5,000 m to 8-10 liters/min at an altitude of 12,000 m. The consumption of oxygen with a switched-on continuous supply of oxygen at altitudes from 12,000 to 15,000 m reaches 15-20 liters/min.

The disadvantage of oxygen apparatus with oxygen supply under increased pressure lies in the increased resistance during the expiration as compared with the other apparatus, so that, during the expiration, it is necessary to overcome every time the resistance of the increased pressure created in the space under the mask. This may lead to rapid fatigue of the pilot. In addition, during the respiration /124 under increased pressure certain difficulties in blood circulation may arise.

In order to protect against the untoward phenomena connected with breathing under increased pressure, oxygen apparatus with excess pressure is used together with the compensating suit.

Compensating suit is a special type of suit with a built-in pneumatic system which adheres tightly to the trunk and to the extremities. At the same time as excess pressure is applied under the mask, counter pressure is applied automatically to the surface of the body by tensioning the pneumatic system of the suit. Due to this, the difficulties in respiration and blood circulation are eliminated to a certain extent. The compensating suit is used with an excess pressure exceeding 25 mm Hg. The latest models of compensating suits serve also as anti-gravity suits.

The experience gained in using oxygen apparatus with excess pressure and compensating suits has taught us that it is always necessary to carry out special preliminary training on respiration under conditions of increased pressure.

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CHAPTER VII

ACCELERATION DURING FLIGHT IN AIRCRAFT AND ITS INFLUENCE ON THE HUMAN BODY

During his long evolution, man has adapted himself to specific conditions of existence and to a certain speed of locomotion.

Fifty-sixty years ago the highest velocity which man encountered in his everyday life did not exceed 45-50 km/hour. Velocities associated with transportation have increased continuously with the development of science and technology and particularly during recent years the development of internal combustion and jet engines enabled man to reach very high velocities, considerably in excess of the speed of sound. This rapid increase in the rate of movement of aircraft has brought to the fore the problem of the limits of tolerance of the human body to high accelerations. This problem is particularly acute in military aviation.

Aviation medicine is faced with a problem of comprehensive and thorough study of the influence of acceleration on the human body and of finding means of eliminating or alleviating the harmful effects of acceleration.

From the point of view of pilot performance, high-speed flight is undoubtedly considerably more complicated and difficult than flight at low speeds. However, the velocity itself has no effect on the human body. Provided there is adequate protection against cross air-currents, a man inside a closed cabin can withstand any speed if the direction of the movement of the aircraft and the speed remain unchanged. In other /126 words, there are no physiological limits of endurance of a human being to velocity if the aircraft continues in a straight-line uniform motion. However, military aircraft frequently change the direction and speed and the resulting mechanical forces exert definite influence on the body of the pilot.

Physical Nature of Acceleration

Any change in magnitude or direction of the speed per unit of time is referred to as "acceleration".

The acceleration is proportional to the force acting on the body and inversely proportional to the mass of the body. This is one of the important laws of mechanics. It is expressed mathematically as follows:

$$a = \frac{P}{m}$$

where P = forces acting on the body; m = mass of the body.

It is possible to determine from the magnitude of acceleration the magnitude of the force acting on the body.

Acceleration in flight occurs during changes in the magnitude of the speed, while maintaining the direction of motion or, in the case of constant speed, by changing the direction of motion.

Usually, the force of gravity is taken as the unit for measuring the forces bringing about acceleration. The force of gravity gives a freely falling object in a vacuum an acceleration of 9.81 m/sec^2. This enables defining the acceleration occurring for any type of motion in multiples of the acceleration caused by the gravitational forces. It follows from the acceleration during free fall that the acceleration of 9.81 m/sec^2 is caused by the effect of the force corresponding to the weight of the body.

If the acceleration equals 5 g, this means that the force produced is five times that of the weight of the object.

Movement of an aircraft in air is rarely along a straight line with a constant velocity. During flight, the aircraft frequently changes its speed and its direction of motion. Therefore, accelerations occur during flight.

The most frequent types of acceleration which occur during flight are the accelerations during rectilinear and curvilinear movement, i. e. centripetal accelerations.

Accelerations During Rectilinear Motion of Aircraft /127

Acceleration during rectilinear motion of aircraft occurs in the case of changes in the magnitude of the speed while maintaining constant the direction of motion. In the case of rectilinear motion, two types of acceleration can occur; positive and negative, acting upon the body in the transverse direction.

Positive acceleration occurs during accelerated motion when the magnitude of speed increased per unit of time. Acceleration in that case is in the direction of motion.

Negative acceleration occurs during slowing down, i. e. when the speed decreases per unit of time. In this case, the acceleration will be in the direct opposite to that of the direction of motion.

Acceleration, in aviation, during rectilinear motion occurs relatively frequently. Accelerations of small magnitude during rectilinear motion of an aircraft occur during every take-off (positive acceleration) and during landing (negative acceleration).

Accelerations occurring during take-off and during correct landing of an aircraft are usually within the limits of 1 g and act for a few seconds; these accelerations have no appreciable effect on the pilot.

In some cases, the accelerations reach great magnitudes and their effect on the human body can be quite considerable. Such accelerations occur when catapulting an aircraft from an aircraft-carrier, when ejecting the pilot from the aircraft and during ordinary parachute drops.

The rectilinear negative accelerations assume considerable values during any type of emergency landings of aircraft. In such cases, the acceleration may reach several tens of g's and, in some cases, may be fatal to the human body. The magnitude of the negative acceleration during emergency landing of aircraft can be calculated according to the formula:

$$a = \frac{v_t^2 - v_o^2}{2S}$$

where a = magnitude of the acting accelerations in g;

v_t = initial velocity, m/sec;

v_o = final velocity;

S = distance traveled.

Let us assume that the landing speed of the aircraft equals 300 km/hr = 83 m/sec. The final velocity obviously equals zero. During landing on the fuselage (belly-landing) the distance of travel of the aircraft on the ground is 20 m. Assuming a constant deceleration the average deceleration will be: /128

$$a = \frac{v_t^2 - v_o^2}{2S} = -\frac{83^2}{2.20} = -172 \text{ m/sec}^2, \text{ approximately } -17.2 \text{ g}.$$

The negative sign indicates that the acceleration is in the direction opposite to the direction of movement.

Negative acceleration also develops during parachute jumps at the instant of opening the parachute. After the parachutist jumps out of the aircraft and falls freely, he is subjected to the resistance of the air, which increases as he approaches the ground, this being due to the increasing density of the air. The resistance of the air is in the direction opposite to the direction of movement of the body and therefore the acceleration during the fall starts to decrease from a certain instant of time onwards. As a result, after a few seconds of free fall, the air-resistance acting on the parachutist is in equilibrium with the force of gravity, the acceleration of the fall stops and the parachutist falls with a constant velocity, the value of which depends on the air density.

If the parachute cord is pulled at an altitude of 2 - 3 km, the parachutist will assume a constant speed 11 - 12 sec after jumping out of the aircraft. This speed will be about 50 - 60 m/sec. If the parachute cord is pulled at higher altitudes, the constant speed will be established after a greater time lag and will be considerably higher due to more rarefied air. For instance, if the cord is pulled at an altitude of 12,000 m, the constant velocity will be established after a time lag of 18 - 20 sec and will reach 90 m/sec.

The parachute has a high aerodynamic resistance due to its large surface area (50 - 60 m^2) and its spherical shape and, therefore, when opened it rapidly brakes the fall of the parachutist. The opening of the parachute and the braking is in the form of a shock. Thereby the magnitude of the acceleration varies within wide limits and depends on a number of factors.

The main factor determining the magnitude of acceleration during opening of the parachute is the velocity of fall of the parachutist.

On opening the parachute at 1,000 m after falling for 15 sec, the acceleration reaches about 6 g; at an altitude of 11,000 m under the same conditions the acceleration is about 18 g. /129

When an aircraft is catapulted from the deck of an aircraft-carrier, high positive accelerations result along a straight line. The magnitude of the acceleration depends on the speed at which the aircraft is ejected from the catapult and on the length of the catapulting. If the speed of ejection is increased or the distance of travel in the catapult is reduced, the acceleration will obviously increase. On catapults of modern aircraft-carriers the acceleration is about 1.5 sec. The direction of acceleration is at right-angle to the longitudinal axis of the body, i. e. from back to front.

Due to the comparatively small magnitude, short duration and favorable direction, in most cases acceleration will not result in any injuries to the organism.

Acceleration During Curvilinear Motion of an Aircraft (Radial Acceleration)

In military aviation, particularly in fighters, acceleration during curvilinear motion is considerably more frequent than rectilinear motion, and furthermore accelerations of an equal magnitude during curvilinear and rectilinear motion have different effects on the human organism. Thus, accelerations during curvilinear motion are accompanied, in most cases, by greater physiological effects than accelerations during rectilinear motion.

During its flight, an aircraft performs a number of evolutions in conjunction with change in the speed and direction of movement. This evolution produces so-called "radial" or "centripetal" accelerations.

If we know the radius of curvature r, along which the aircraft travels, and its linear velocity v, the centripetal acceleration can be calculated according to the formula

$$a = \frac{v^2}{10r}$$

It can be seen from this formula that during curvilinear motion of the aircraft an acceleration acts on the pilot, the magnitude of which is directly proportional to the square of the speed and inversely /130 proportional to the radius of the curve along which the aircraft travels. Centripetal acceleration is always directed towards the center of the circular movement.

An example of curvilinear motion of an aircraft with a relatively constant flight speed is a correctly performed turn of the aircraft.

Let us assume that the velocity of an aircraft during a turn is 720 km/hour = 200 m/sec and the radius of turn is 1,200 m; in this case, the centripetal acceleration will equal

$$a = \frac{200^2}{1200 \cdot 10} = 3.33 \text{ g}$$

If the radius of curvature is made smaller, the magnitude of the acceleration will increase. Thus, the acceleration will equal 6.66 g for a radius of 600 m and the same flight speed.

The magnitude of acceleration also increases with increasing speed of the aircraft. An aircraft traveling at 1,080 km/hour will develop an acceleration of 7.5 g when turning on a radius of 1,200 m.

Thus, the acceleration during curvilinear flight depends on the flight speed and radius of curvature. Acceleration increases with increasing flight speed and decreasing radius of movement of the aircraft.

In addition to the above example, centripetal acceleration occurs during all flight maneuvers such as Nesterov loops, inverted loop, diving, etc. Accelerations during maneuvering an aircraft differ in magnitude and duration. Thus, for instance, when the Nesterov loop is made, the accelerations during certain time intervals may reach 6 g for durations of 3 - 4 sec.

The greatest accelerations occur during diving of an aircraft. Diving means descent of an aircraft at an oblique angle and subsequent maneuver of the aircraft into horizontal flight. At the instant of maneuvering the aircraft from diving into horizontal flight, acceleration of 8 - 9 g and 0.5 sec duration may occur in modern aircraft.

During curvilinear motion of aircraft, radial accelerations may occur in different directions relative to the human body; from the feet to the head; from the head to the feet; from back to front; from right to left and from left to right.

The most frequently encountered radial accelerations during flight in modern aircraft are directed from the feet to the head and, much more rarely, from the head to the feet (during aerobatics while flying upside down). /131

Since the accelerations are caused by external forces, there is a strict interrelation between the forces acting on the body and the acceleration which is defined by the second law of Newton: "Acceleration is proportional to the acting force and is in the same direction" or, in other words, "the product of the mass of the body and its acceleration is equal to the force acting on the body".

Knowing the magnitude of acceleration, it is easy to determine also the magnitude of the centrifugal force exerted by the pilot.

Since the magnitude of the centrifugal force is equal to the product of the mass and acceleration, its magnitude can be determined from the formula

$$F = m \cdot a,$$

where F = centrifugal force,
m = mass,
a = acceleration.

At the instant of pulling-out of a dive, the force acting on the body of a pilot weighing 70 kg, in the case of an acceleration of 7 g, will be

$$F = 70 \cdot 7 = 490 \text{ kg}.$$

In addition, the pilot will be subjected to the force of gravity equaling 70 kg. As a result, the equivalent force acting on the pilot will equal 490 + 70 = 560 kg.

The direction of the centrifugal force will always be opposite to the direction of the radial acceleration.

The term "overload" is frequently applied in aviation medicine and engineering. By "overload" we understand the ratio of the force acting on the body to its weight. If, in the given case, when the aircraft pulls out from diving the equivalent of the two forces which press the pilot to his seat (i. e. the apparent weight) equals 560 kg, the overload will be

$$n = \frac{560}{70} = 8.$$

The overload is a dimensionless quantity.

In a manner similar to centrifugal force, the direction of the overload will be opposite to the direction of acceleration, i. e. during acceleration it will be against the direction of movement while during deceleration it will be in the direction of movement. /132

The overload is referred to as"longitudinal", relative to the human body, when it is in the direction along the longitudinal axis of the body; "transverse" when it is at a right angle to the longitudinal axis of the body; "lateral" when it acts from right to left or from left to right.

If the overload is in the direction from the head to the feet, it is referred to as "positive". If it is directed from the feet to the head (maneuvering the aircraft into diving, reverse loop, etc.) the overload is arbitrarily called "negative".

Effect of Acceleration Occuring During Rectilinear Motion on the Body of a Pilot

The positive accelerations arising during take-off and gaining of speed do not have an unfavorable effect on the pilot. This is explained by the fact that the magnitude of these accelerations is insignificant and the acceleration acts in a direction which is most favorable from the point of view of the organism.

No untoward effect was observed due to the positive accelerations occurring during catapulting of an aircraft from an aircraft-carrier, when the acceleration may reach 5-6 g.

Data on laboratory investigations have shown that at accelerations of 6.0 to 8.0 g breathing becomes somewhat difficult in view of the compression of the thorax. However, even at accelerations of 12 g no noticeable disorders in the human body occur, provided the trunk and the head of the body are sufficiently firmly supported.

Experiments on animals have shown that even accelerations of 16.0 g, acting in the direction from chest to spine and from spine to chest for several dozens of seconds, will not produce unfavorable after-effects.

In aviation negative accelerations during rectilinear motion, which occur during emergency landings of aircraft and during accidents, when the magnitude of acceleration may reach several tens and, in some cases several hundreds of g's, are of much greater importance. These accelerations, very frequently, damage the skull and internal organs.

Effects of Radial Accelerations on the Body of the Pilot /133

Radial accelerations occur during maneuvering (aerobatics). Disorders in the organism occurring during radial accelerations depend primarily on the direction of acceleration. The character of the disorders depends on the magnitude and duration of accelerations.

An acceleration of 2.0 g only produces a sensation of being pressed to the seat. Acceleration of 3.0 g presses the pilot more firmly to the seat and movement of the hands and feet is somewhat impeded. During accelerations of 3.5 to 4.5 g, the sensation of heaviness of the body and its extremities is still more pronounced. It is only with considerable effort that the pilot can remain in a seated position. However, if the acceleration acts for a longer time, clouding of the vision may frequently occur - a gray mist will appear in front of the eyes. In the case of accelerations of 4.5-5.0 g, the pilot can carry out only slight movements with his hands and legs and even that only at the expense of a major effort. The sight is still more impeded. Arbitrary movement becomes extremely difficult at accelerations of 5.0-5.5 g; a black veil will appear before the eyes of the pilot, as a result of which the vision is strongly affected. There will be, in addition to this, disorders of the rhythm and depth of breathing and acceleration of the pulse rate. A sudden loss of consciousness may occur at an acceleration of 6.0 g. Consciousness returns rapidly after the effect of acceleration is stopped but the clarity of mind remains impeded for some time.

Under the influence of centrifugal forces the internal mobile organs move downwards at the instant of acceleration. Special cine-film experiments have shown that during aerobatics the eyelids drop and the muscles and skin of the face sag. Apparently the same occurs with the soft tissues of the trunk.

The most mobile tissue of the body, however, is the blood. Therefore, at the instant of radial acceleration circulatory disorders are the most important. In all cases of curvilinear flight, acceleration acts on the body of the seated pilot in the direction which coincides with the direction of the large arteries distributed along the body. Thus, favorable conditions occur for displacing the blood and the blood tends to move in the direction of the acting force, which is opposite to that of the acceleration. /134

When acceleration is in the direction feet-to-head, less blood will flow in the blood vessels of the upper part of the body and there will be a rush of blood into the vessels of the lower extremities and the abdominal cavity. The blood pressure in the blood vessels of the head and the upper part of the body will decrease, while in the vessels of the lower extremities and the abdominal cavity, it will increase.

Experiments on animals have shown that in the blood vessels of the head the blood pressure decreases on an average by 20 - 30 mm Hg for each unit of acceleration, the drop in blood pressure beginning not immediately at the instant of acceleration but about 0.5 sec later. A reduction in blood pressure and decrease in blood volume of the heart cause reflex acceleration of the pulse rate. In human beings the pulse rate may increase to within 120-180 per minute for an acceleration of 5.0 - 5.5 g.

Displacement of blood in the blood-circulation system causes excitation of a large number of nerve endings which are located in the walls of the blood vessels. The resulting nerve impulses are transmitted to the central nervous system, where they cause a number of reflex reactions which are aimed at re-establishing the blood circulation. In the case of small accelerations of short duration, these reflex reactions fully compensate the disturbance in the blood circulation and there will be no adverse effects in the organism. If, however, the accelerations reach considerable magnitudes and their duration is relatively long, the compensating reactions become inadequate. In this case, inadequate blood supply to the brain leads to a sharp oxygen deprivation of the cells of the central nervous system, which causes a whole series of disturbances. As a result, there will be a decrease in the speed of reflex reactions, an impairing of the memory, derangement of the fine coordination of movements, weakening of the muscle forces, impairment in the perception of a given muscular effort, impoverishment of the powers of concentration, etc.

However, the most intolerable and dangerous consequence is a loss of consciousness, which may be preceded by short-duration dimmning of the consciousness.

According to Soviet and foreign data, loss of consciousness of flying personnel may set in at accelerations of 5.0 - 6.0 g for periods exceeding 3 sec. After acceleration has ceased, consciousness is re-established after a few seconds. However, it may remain at reduced level for a certain period of time. /135

Of the effects of radial acceleration - visual disorders are most common. According to present-day understanding, this is basically due to the disturbance in the blood circulation of the retina. The seriousness of visual disturbances increases gradually. At first, dulling of the vision is noticed and the appearance of a gray mist, then a narrowing of the field of vision and, finally, complete loss of vision.

Dulling of the vision during flight is frequently observed even at accelerations of 4.0 - 4.5 g, while complete loss of vision occurs at 5.0 - 5.5 g. The character of the visual disorders depends not only on the magnitude of acceleration but also on its duration. (With increasing duration of acceleration the visual disorders become greater.) Visual disorders begin to manifest themselves at the instant when the blood pressure in the blood vessels of the retina drops below the pressure inside the eye. Thereby, the blood circulation in the retina stops and the cells of the retina become very much deprived of oxygen. Dimming of the vision is observed if the blood circulation in the retina is only partly deranged, while if the blood circulation is completely stopped a complete loss of vision will result.

The effects of radial accelerations on the human organism, directed from the feet to the head, have been described earlier. However, in flying practice, cases may arise in which radial accelerations act for several seconds in the direction from the head to the feet (negative overload). In such cases, even an acceleration of 1.5 g will produce a sensation of pressure in the head. In the case of an acceleration of 2 g the pressure will increase, the vision will be slightly dimmed and a pain will appear in the neighborhood of the eyes, together with tears and, in some cases, also dizziness. Accelerations of 2.5 - 3.0 g bring about a still greater increase of pressure sensation in the head and in the abdominal cavity. Breathing becomes more difficult as the field of vision shifts into the red part of the spectrum and, in some cases, nosebleeding occurs. Accelerations of 4.0 g will bring about an intensive rush of blood to the head, the facial skin will become extremely stressed, sharp pains will occur in the eyelids, the flow of tears will be intensified and all the surrounding objects will appear red, the skin of the face will be red and swollen, numerous punctiform hemorrhages will appear on the skin of the face and the conjunctiva and, finally, sharp headaches and dimming of the consciousness. /136

These phenomena, which occur during acceleration, are due to the impairment of the blood circulation. There is a redistribution of the blood from the vessels of the lower extremities and the abdominal cavities, in the given case, into the vessels of the upper part of the body and the head. The blood pressure in the vessels of the brain increases as a result. The increase in this pressure will be the higher, the higher the actual acceleration.

It is pointed out that negative overloading during flight is tolerated by the pilot with greater difficulty than positive accelerations.

Limit of Tolerance to Radial Acceleration

That acceleration should be considered as tolerable which does not produce serious disorders in the organism or, in other words, which produces insignificant and rapidly passing symptoms. Since vision is affected in the first place as a result of acceleration, the appearance of a gray mist in front of the eyes of the pilot is considered as a criterion of tolerable acceleration.

Soviet research workers investigating flying conditions at various altitudes have obtained extensive material on the basis of which it is possible to arrive at values of tolerable accelerations and factors which influence the tolerance to accelerations.

Among the numerous factors which determine the ability of a human being to withstand the radial accelerations are the following: magnitude of acceleration, direction of acceleration, duration of acceleration and individual characteristics of the organism.

In an ordinary sitting position the pilot in the cabin of an aircraft will find tolerable over short periods (1 - 2 sec) radial accelerations up to 5 g if the centrifugal force acts in the direction head-to-feet without visual disorders, while fully maintaining his working capacity. If such accelerations last for fractions of tenths of a second, well-trained test pilots can tolerate them at a level of 7-8 g and, in some individual cases, even up to 9.0-9.5 g. However, if the effect of radial acceleration is prolonged for several seconds the functions of the organism may be affected at considerably lower magnitudes of acceleration. Thus, for instance, if the acceleration lasts for 10 seconds, untrained people suffer a dimming of vision and a narrowing of the field of vision /137
at accelerations of 3.0-4.0 g, a complete loss of vision at 4.5 g and loss of consciousness at 5.5-6.0 g. However, it is necessary to point out that people who have been well trained on centrifuges can tolerate satisfactorily accelerations of 4 g for periods of 3 minutes.

When discussing the limit of radial accelerations tolerated by the human body, it is necessary to take into consideration the individual features of the resistance of the pilot to accelerations, which fluctuate within relatively wide limits together with a number of interdependent factors.

It is necessary to understand that under any conditions the duration of the accelerations is of primary importance. The shorter the duration, the easier the body can withstand them. Experiments have shown that a human body will withstand, without appreciable disturbance of vision and of the central nervous system, straight-line accelerations of 20.0 g for periods of 0.1 - 0.2 sec. It is assumed that instantaneously acting radial accelerations of even very high values will hardly be felt by the pilot.

In addition to the time factor, the resistance of the body to accelerations depends to a considerable extent on the direction of the acceleration. Thus, for instance, the resistance of the body to radial accelerations in the direction from head to feet is considerably lower than in the direction from feet to head. For accelerations from head to feet, the limit tolerable acceleration which does not produce any particular disorders is 2.5 - 2.8 g.

On the other hand, the resistance of the body to radial accelerations increases considerably if it is at an angle (to the acceleration vector) and the increase will be the greater the more the angle approaches the perpendicular to the longitudinal axis of the human body. If the acceleration acts at an angle of 45° the tolerance increases by 1.5-2.0 g; in centrifuge experiments the tolerance for radial accelerations lasting several tens of seconds was 14.0-16.0 g.

An increase in the resistance of the organism to radial accelerations while in the lying-down position is explained by the fact that acceleration at a right-angle relative to the longitudinal axis of the body is less disturbing to the blood circulation and the displacement of the internal organs is also smaller.

Finally, it is pointed out that the resistance of the body to accelerations is considerably reduced under conditions of oxygen starvation as well as in the case of weighing down the organism in the aircraft cabin during flight or prior to flight. /138

Means of Increasing the Resistance of the Body to Radial Accelerations

At the present state of aviation development, the problem of increasing the resistance of the body to radial acceleration is extremely acute. This problem can be solved successfully only by close cooperation between aircraft designers, pilots and medical aviation personnel. There is no doubt that on further increase in speed the most important problem will be to provide technical means and measures permitting increasing considerably the tolerance to accelerations. However, this does not reduce the problem of increasing the resistance to accelerations of the human organism itself, which is achieved by numerous special measures.

Systematic flight training. Systematic flight training is the most effective means of increasing the resistance of the body to accelerations. It gives extremely favorable results if the acceleration and complexity of the piloting are increased gradually. Thereby, flight habits and techniques are perfected and the cardio-vascular system and neuroreflectory mechanisms are trained. During the flight training, the pilot becomes accustomed to acceleration, while avoiding excessive overloads and evaluating correctly his resistance to acceleration, taking it all calmly. Furthermore, during flight training conditioned reflexes are produced, as a result of which compensating mechanisms intervene even before the onset of acceleration, increasing in this way the tolerance.

If a pilot is subjected to the effect of acceleration several times during a single flight or during several flights in a single day, the tolerance to acceleration of inadequately trained pilots decreases, as a result of the accumulative effects of the acceleration.

Physical training. Physical training of flying personnel is of extreme importance from the point of view of increasing their resistance to acceleration.

The physical-training exercises should include the toning up of the muscles of the abdominal region as well as the muscles of the lower extremities. Experience has shown that if the abdominal muscles are stressed the pilots can tolerate acceleration more easily. This is explained by the fact that during contraction of the abdominal muscles the intra-abdominal pressure increases and, as a result of this, a barrier is created, preventing the displacement of the blood into the blood vessels of the abdominal cavity and of the lower extremities. /139

In addition to exercises of this type, physical training should be aimed at improving the physical condition and particularly the cardio-vascular system of the air crew. For this purpose, exercises on apparatus, skiing, skating and swimming are recommended.

Anti-gravity and compensating suits. The problem of producing effective devices counterbalancing the effects of increased gravity has been under consideration in the USSR as well as in other countries for a long time. The idea is to produce suitable equipment which exerts a pressure on an area of the body and on the lower extremities for the purpose of producing a barrier preventing the displacement of the blood from the vessels of the upper half of the body into the vessels of the abdominal cavity and lower extremities during radial acceleration. Solution of this problem was sought by designing various types of equipment.

During recent years the most widely used approach has been the so-called antigravity suit with pneumatic action. It consists of wide cuffs placed at the region of the abdomen, thighs and shins. All these cuffs are interconnected and connected through a special regulator to the supercharging system of the cabin. At the instant radial acceleration sets on, the pressure in the cuffs is automatically increased to the required values. In view of the extensive use in recent years of oxygen equipment with compensating suits and high-altitude suits, the antigravity equipment is combined with the compensating suit and high-altitude suit.

Antigravity equipment increases the tolerance to radial acceleration by 2.0-2.5 g.

Environmental conditions of the pilot. The resistance of the organism to acceleration depends on the state of the body. A correct planning of the day's activities, of rest and of eating increases the tolerance to acceleration. Over-tiredness, inadequate sleep, excessive smoking, alcohol consumption, sickness, depression, etc. considerably /140
decrease the resistance of the body to acceleration. The resistance of the body to acceleration is also reduced by flying on an empty stomach as well as flying immediately after consuming an excessively large meal. Therefore, pilots should eat about 1.5-2 hours prior to take-off.

The position of a pilot's body. It was mentioned earlier that if the acceleration is applied at an angle, and particularly if it is applied perpendicularly to the longitudinal axis of the body the tolerance to radial accleration increases sharply.

It can be assumed on this basis that solution of the problem of increasing considerably the tolerance to radial acceleration in modern aviation and in future aviation should be reached by changing the direction of the acceleration relative to the body of the pilot, i.e. by changing the position of the pilot.

It can be seen from the data given that a horizontal position of the pilot in the cabin will increase appreciably his tolerance to radial accelerations. However, such a change in the position of the pilot creates a number of other disadvantages from the point of view of work and involves technical difficulties.

CHAPTER VIII /141

PHYSIOLOGICAL-HYGIENIC FUNDAMENTALS OF EMERGENCY RESCUE MEASURES AT HIGH ALTITUDES

In case of emergency during flights at high altitudes, the human body may be subjected to the effects of: very acute oxygen deprivation, explosive pressure drop, rarefied atmosphere and low temperature of the ambient air.

The most dangerous of these factors is the acute oxygen deprivation.

If the cabin of the aircraft develops a leak at a high altitude and there are no appropriate means of ensuring immediate oxygen supply to the organism, the pilot may lose consciousness within 7-10 seconds.

It is understandable that during such a short period the pilot cannot take effective rescue measures to eject himself or descend to a safe level.

High rarefaction of the atmosphere may cause decompression disorders as well as boiling of the semi-liquid matter of the body, which will be accompanied by swellings under the skin.

Therefore, it is perfectly clear that flights at very high altitudes and at very high velocities are safe only if reliable means of protection of the crew are available which include:

- scaphanders, the pressure in which, as well as the pressure in the hermetically sealed cabin, is in excess of that of the surrounding atmosphere; in the scaphanders an absolute pressure is maintained within the limits of 170-145 mm Hg, which corresponds to altitudes of 11,000- /142
12,000 m. Such a pressure in the space inside the scaphander ensures, in the case of breathing pure oxygen, the necessary partial oxygen pressure in the alveolar air of the lungs;

- special oxygen equipment for breathing oxygen at an excess pressure; such instruments produce automatically under the mark, at altitudes in excess of 12,000 m, a pressure which is higher than that of the surrounding atmosphere and, as a result of this, ensures an increase to the required value of the partial oxygen pressure in the alveolar air;

- a special high-altitude compensating suit which is used in the case of breathing oxygen at an excess pressure for the purpose of creating a counter pressure on the trunk and on the extremities; the high-altitude compensating suit permits producing higher excess pressures and thus obviates difficulties of breathing and blood circulation and the appearance of swellings under the skin;

- special ejecting equipment for rescuing the crew if it becomes necessary to abandon the aircraft.

Ejection of the Pilot

The study of the effects on the human body of accelerations associated with motion in a straight line has gained considerably in importance during the last few years as a result of the necessity of ejecting pilots during emergency situations arising in flight.

By ejection is understood forced throwing out of the pilot from the cabin of the aircraft, together with his seat, to a safe height, from where it is possible to descend with a parachute.

Aviation experience has shown that without ejection equipment the pilot can abandon the cabin of the aircraft up to a velocity not exceeding 400 km/hour. At this velocity a pilot of average physical fitness will still have the power to overcome the air resistance. At a velocity of 450 km/hour it becomes very difficult and dangerous to abandon the aircraft unaided, since the force of the air resistance in this case is eight times as high as the weight of a pilot's body and there is a possibility of hitting the fuselage and the tail group. If the flight velocity reaches 500-600 km/hour, it is no longer possible to /143
abandon the cabin without ejection since the air resistance in this case exceeds the weight of a pilot's body by 10 to 15 times. Furthermore, at such velocities it is difficult to avoid hitting the fuselage or the tail group.

Statistical data show that, out of 1178 parachute drops from high-speed aircraft not fitted with ejection equipment performed by pilots of the German Air Force, pilots suffered various types of serious injury in 158 cases, during the Second World War.

Of the American Air Force pilots who abandoned high-speed aircraft in 1943 by means of parachutes, 24% suffered serious injuries. These examples alone show the need for fitting modern aircraft with special devices in order to make the escape from the cabin safe.

The most reliable means of safe escape are ejection devices which ensure the following:

- abandoning of the aircraft by the pilot (members of the crew) in the shortest possible time, which is of extreme importance for present-day operational speeds and altitudes;

- abandoning the aircraft and overcoming the high air resistance without any effort on the part of the pilot;

- safe abandonment of the aircraft without the risk of hitting the fuselage or the tail group;

- possibility of abandoning the aircraft if the pilot is wounded etc.

Aircraft ejection equipment consists of a special seat, a firing mechanism and guide rails; there is a recess in the form of a cup for the seat of the pilot (the crew members), handrails, footrest and safety harness.

In modern aircraft the ejection of the pilot is mostly upwards and is actuated by the gases formed during the firing of the charge. For this purpose a special device with an explosive charge is placed under the seat of the pilot which can be brought into operation by pressing a button located on the handrail or by moving a special blind fitted into the headrest.

The energy of the explosive charge should ensure the ejection of the seat, together with the pilot, to an altitude of 17-18 m with a velocity of 18-20 m/sec. Such altitude and velocity of ejection are essential for aircraft flying at a velocity in excess of 700 km/hour. /144
The magnitude of the force required for ejecting the pilot depends on the flight velocity and altitude, the angle of inclination of the guide rails, as well as the weight of the pilot and his seat.

During the process of upward ejection there are several forces which act on the pilot, particularly the following:

- positive acceleration if the shock which develops at the instant of explosion of the charge is in the vertical direction;

- pressure of the oncoming air stream;

- negative acceleration resulting from the slowing-down of the horizontal velocity of the seat after it separates from the aircraft;

- negative acceleration due to the dissipation of the vertical velocity of the seat.

Thus, during ejection there will be several forces acting for a short time on the body of the pilot in various directions. At high flight velocities, these forces may reach critical values and for that reason the study of these forces by the flying, technical and medical personnel of the Air Forces is of great importance, with the object of eliminating the unfavorable effects of these forces. To understand more clearly the effect of ejection on the body of the pilot (or on the members of the crew) each stage of ejection will be discussed separately.

Explosion of the Charge at the Initial Back-Kick of the Seat

The maximum acceleration during the initial back-kick applied to the seat during upward ejection may reach 18-20 g. The duration of the acceleration does not exceed 0.1-0.2 seconds. The overload at such acceleration acts in the direction from head-to-feet; i.e. opposite to the direction of acceleration. It would appear that the effect of high overload on the human body should bring about unfavorable after-effects. However, experiments have shown that such overloads, if acting for only 0.1-0.2 seconds, can be withstood by the body without ill effect. The short period during which the overload acts is not sufficient to bring about circulatory and central nervous system disorders to a degree reached in the case of radial accelerations of longer duration. Very large impact overloads, even if of very short duration, may damage the spine. /145 For instance, if the pilot weighs 75 kg, at the instant of an acceleration of 20 g, the apparent weight of the body increases by a factor of 20, reaching 1500 kg. Thus, the enormous force acting during the short period of time will produce a sudden damage in the spine of the pilot. If the trunk is not sufficiently secured to the back of the seat, then, at the initial instant of the impact, the spine will bend at the waist and neck. In such a case the forces act at an angle to the spine and this may damage it. Therefore, the safety harness of the ejector seat is of extreme importance for ensuring the safety of the pilot during ejection. The safety harness should ensure reliable adherence of the body of the pilot to the back of the seat, as well as his rapid separation from the seat after being ejected from the cabin of the aircraft.

Much attention is being paid to automation of the tightening of the harness belts prior to ejection. Usually, in a single lever the following functions are combined: tightening of the harness, ejection of a flashlight, actuation of the firing mechanism etc.

Although the spine at the waist is very strong as compared to the spine at the neck it is particularly the waist part of the spine which becomes damaged most frequently at high overloads and in the case of unfavorable body positions. This is explained by the fact that the waist part of the spine supports the upper part of the body, amounting to 55% of the total weight of the body, while the neck part only supports the head, which forms about 7% of the total weight of the body. The limit load for the neck part of the spine corresponds to accelerations of 47-52 g and for the waist part about 18-26 g. To prevent unfavorable after-effects, it is recommended that during ejection the trunk should fit tightly to the back-rest of the seat, that the feet should be pressed into the footrest, the hands into the handrails and that a correct position is assumed.

To prevent hitting the elbows against the walls of the cabin, much attention must be paid to pressing the arms against the trunk and not to allow them to move about sideways.

Pressure of the Impinging Airflow

The effect of this factor manifests itself from the first instant of ejection. The force of the impinging airflow is determined by the speed of the aircraft. At high speed it may reach enormous values. Thus, for instance, at a speed of the aircraft of 800 km/hour, the pressure of the impinging air reaches approximately 3,100 kg per 1 m^2 and the pressure applied on the human body will reach 1,550 kg. At a velocity of 1,000 km/hour, the pressure of the impinging airflow per 1 m^2 equals 4,760 kg, the pressure on the human body is 2,900 kg, while at a velocity of 2,000 km/hour, the values are respectively 19,300 and 8,000 kg. Therefore, much attention must be paid to supporting the head so as to prevent damage to the neck part of the spine. After ejection, the pressure of the impinging airflow decreases rapidly as a result of a decrease in the velocity of motion of the seat. /146

Experiments on people have shown that a high stream velocity of about 550 km/hour produces painful sensations only when hitting the face. An airflow of 850 km/hour also does not produce any serious damage. However, airflows with velocities of the order of 1,000 km/hour and more may produce various disorders in the functioning of the body. Furthermore, it is necessary to guard against damage to the soft tissues of the face. To prevent the dangerous effects of the impinging air stream encountered during ejection from modern aircraft, special means of protection are used, including a blind fitted to the ejection equipment. The blind protects the face of the pilot from the impinging airflow and enables the pilot to maintain his correct position during ejection, which is a vital condition for ensuring his safety.

During ejection at altitudes of about 18,000-20,000 m and above, the conditions of cabin depressurization approach that of explosive decompression. Therefore, after ejection at such altitudes it is recommended that the opening of the parachute should be delayed in order to shorten the stay in this zone which is dangerous to human beings, as well as to reduce the dynamic impact. Throughout the entire descent oxygen supply is ensured by means of the parachute oxygen apparatus.

Stoppage of oxygen supply during ejection at high altitudes may cause unfavorable after effects. To prevent the dislodging of the oxygen mask, special fastenings have been recently developed which ensure that the mask adheres strongly to the face.

The scaphander ensures reliable protection of the ejected person from the effects of the low barometric pressure, low temperatures and the impinging air streams at flight velocities up to 1,300 km/hour.

Furthermore, the air layer between the scaphander and the body softens the effect of impact accelerations which occur during explosion of the ejection cartridge and the opening of the parachute. /147

The conditions of ejection in an altitude-compensating suit are almost the same as the conditions of ejection in scaphanders.

The most reliable protection against the oncoming airflow is achieved by using rigid containers and detachable aircraft cabins. However, introduction of these means in aviation involves considerable design difficulties.

As soon as the ejector seat with the pilot is separated from the aircraft, the acceleration produced by the explosive charge will cease. However, due to the braking effect of the impinging air stream there will be a horizontal negative acceleration. The overload in this case is in the direction from spine-to-chest. Usually, the higher the velocity of flight the greater will be the acceleration and, consequently, the greater the overload. In most cases of ejection from aircraft, this type of acceleration does not exceed 10 g; its duration is about 4 seconds. Thereby, the magnitude of the acceleration decreases very rapidly, amounting at the end of the first second to only half of the initial value. Experiments have shown that the accelerations, acting in the direction from chest-to-spine and from spine-to-chest, can be easily withstood even if they amount to 14-16 g and last for tens of seconds. Consequently, there is no reason to fear accelerations of the order of 10-12 g acting for periods of about 4 seconds. A healthy person can withstand satisfactorily short duration overloads of even 40-45 g in the transverse direction.

Simultaneously with the horizontal negative acceleration which is due to braking by the impinging air stream, there will also be negative acceleration in the vertical direction; this is due to the fact that the velocity of the seat during ejection decreases.

The overload in the latter case is in the direction from feet-to-head. During ejection from an aircraft flying at a velocity of about 1,000 km/hour, the acceleration may reach 4 g but it will act for only a very short time.

In view of the fact that both negative accelerations act simultaneously, their resultant will assume a more favorable direction, approaching the perpendicular relative to the axis of the body (from spine-to-chest), as a result of which there will be no unfavorable effects caused by these accelerations (in the vertical direction). /148

In some cases of ejection the seat may perform rotary movements after separating from the aircraft and this superimposes on the horizontal and vertical negative accelerations. However, this rotation lasts for only a short time and has no appreciable influence on the working ability of the human body.

It is necessary to realize that for a certain time after ejection a so-called period of after-effects is observed, during which the working capacity of the ejected man is somewhat reduced.

Experience gained with forced ejection from modern aircraft indicates that this method of rescue of the air crew is fully reliable. The magnitude of the positive accelerations during ejection does not exceed 15-18 g. Unfavorable effects are observed only rarely, basically for reasons which have no primary relation to the process of ejection itself.

Ejection at low altitudes (below 200 m) may have highly unfavorable effects, since there is insufficient time for the canopy of the parachute to fill with air. It is pointed out, however, that there have been cases of successful ejection even from altitudes of 150-200 m and even without the pilot assuming a special position.

If during ejection pilots suffered injury, this was due to the fact that they forgot, or had no time, to tighten the harness and to assume the correct preparatory position. Being ejected in an inclined position with their elbows spread out and forgetting to put their feet onto the footrest, they became subjected to accelerations in extremely unfavorable directions, hitting the walls of the cabin with their hands or feet, etc. If the ejection is performed correctly, the result will always be satisfactory. This is brought about to a considerable extent by training on the ground, which has proved to have very satisfactory results. The aim of this training is not only to accustom the pilot to assume the correct position and to carry out the ejection itself, but also to acquaint him with the effect of accelerations on the body, by showing him a safe and reliable method of abandoning aircraft.

Ground ejection training is carried out on training ejectors NKTL-3. If the relevant rules of the ground training of ejection are obeyed, the /149
impact accelerations encountered during the explosion of the cartridge (8-12 g) are perfectly safe.

Training on the NKTL-3 equipment will develop in the pilot the right habits which are necessary for ejection during flight.

The success of training is enhanced by correct organization of physical training, work and rest planning, good familiarization with the details of the trainer and its use mastering the sequence of all the actions and movements which have to be performed during ejection from the aircraft, good organization and full knowledge of the effects of ejection on human organism.

For the purpose of safety in training ejectors, the flying personnel should assume a vertical position of the body in the seat, should immobilize correctly the trunk by means of the harness, and ensure comfortable support to the parts of the body on the footrest, handrails, back and headrest.

Experience in ejection training carried out in Air Force units shows that if the above rules are obeyed, no unfavorable after-effects occur.

The flying personnel value very highly the ground ejection trainer devised by Engineer Borshchevskiy. This training equipment permits ejection training for the purpose of developing the habits which have to be applied during ejection from the cabin of an aircraft upwards or downwards, as well as in controlling the parachute and landing.

The trainer of Borshchevskiy enables training in the following individual elements: preparatory body position, process of ejection from the cabin of an aircraft, fall together with the seat, separation from the seat, opening of the parachute and descent turning while suspended, as well as the rules of landing on the ground (or descent on water).

Training by means of the Borshchevskiy trainer is very effective and safe.

The continuously increasing aircraft velocities require corresponding increases in the ejecting force. This leads to the increase of the positive accelerations acting on the pilot. However, accelerations exceeding 20 g are dangerous to the health of man. Therefore, it is necessary to find effective methods of rescuing the crews of aircraft flying at supersonic velocities.

In order to solve these problems it is proposed to design equipment /150
which would bring about deceleration of the aircraft prior to ejection, as well as to design cabins which will break away from the aircraft, with subsequent ejection of the pilot when the velocity of the cabin has dropped considerably.

In recent years experimental work on the possibility of ejecting the pilot downwards has proved successful.

Use of a Parachute

The parachute is intended for reducing the speed of fall of a person to 5-7 m/sec and the use of a parachute is considered to be one of the most important conditions of flight safety. Descending by parachute started with the invention of the parachute by the Russian inventor Kotel'nikov. The principle of design of this parachute forms the basis of modern parachutes as used in the air forces of all countries.

The body of a parachutist falling in the air is subjected to the force of gravity which gives him an acceleration of 9.81 m/sec^2 and to the force due to air resistance acting in the opposite direction.

The magnitude of the resistance depends on the velocity of the falling body, air density, dimensions and shape of the body and on the nature of its surface. Primarily, the resisting force depends on speed of fall of the parachutist. Thus, if the speed of fall of the parachutist increases by a factor of 2, the resistance increases by a factor of 4, etc. For a parachutist air resistance is beneficial: the greater the air resistance the lower the speed of descent and the better will the parachute fulfill its task. The body of a parachutist falling in air is exposed to a relatively large resistance. After a certain time has elapsed from the beginning of the fall, the air resistance will balance the force of the weight. From that time onwards the body of the parachutist assumes a terminal, or so-called equilibrium, velocity - the body will fall in a straight line at uniform rate. However, since the density of air varies with altitude, the air resistance will increase on approaching the ground. This explains why the speed of fall of a parachutist at high altitudes is considerably greater than at low altitudes.

The speed of fall of a parachutist at various altitudes and the time required to reach that speed are given in Table 16. /151

Altitude, km / Velocity and time	1	2	4	6	8	10	12	14	16	18	20
Maximum velocity, m/sec	50	53	59	66	73	81	90	102	115	132	150
Time to achieve this velocity, sec.	12	12.5	14	15	16.5	18	19.5	21	23	23.5	28

Table 16

As can be seen from the table, at altitudes of 1,000 to 6,000 m the equilibrium speed of fall of the parachutist is within the limits of 50-60 m/sec.

The magnitude of acceleration from the beginning of the fall to the attainment of an equilibrium speed is insignificant and does not have an appreciable influence on the parachutist.

The effect of the acceleration on the falling parachutist manifests itself primarily at the instant of opening the parachute when sharp braking sets in and this manifests itself in the form of a dynamic impact.

There are also rectilinear negative accelerations at which the overload acts in a direction from feet-to-head. The duration of the acceleration ranges from 0.1-1 sec. When the parachutist falls at 50-60 m/sec, the magnitude of the dynamic impact lies within the limits from 2.5-3.5 g.

It is believed that the maximum permissible acceleration during opening of the parachute should not exceed 7-8 g.

The dynamic impact will be the greater the higher the speed of the (free) falling parachutist, the greater the area of the parachute and the faster it opens up fully.

If the parachute is opened at a higher altitude, the dynamic impact is considerably greater than at a lower altitude. This is explained by the fact that the force of impact on opening the parachute depends on the real velocity of the parachutist relative to the air and is almost independent of the density of the air that fills the canopy of the parachute.

If near to the ground the speed of a falling parachutist is about 50 m/sec and at an altitude of 12,000 m it is 90-100 m/sec, then opening up of the parachute at an altitude of 12,000 m will produce a dynamic impact which is 3-4 times as large as the corresponding impact produced near ground level.

The force of the dynamic impact may assume very high values, particularly if the pilot opens the parachute immediately after jumping out of the aircraft without waiting for the cessation of his horizontal /152
movement. If, for instance, the pilot ejects himself from an aircraft flying horizontally along a straight line with a velocity of 400 km/hour (110 m/sec) and opens his parachute immediately, the magnitude of negative rectilinear acceleration will equal 10.4 g. The overload arising at such accelerations is dangerous since it may tear the parachute and it may also injure the pilot. This danger is greater still in jet

aircraft. Therefore, after leaving the aircraft (height permitting), it is advisable to wait several seconds until the equilibrium speed of fall is established and only then open the parachute.

This is dictated by the necessity of reducing the time during which the pilot is at a high altitude where oxygen starvation is most dangerous, as well as by the necessity of dissipating some of the (vertical) velocity of fall.

Experience has shown that if the parachute is opened at altitudes up to 8,000 m, the absence of auxiliary oxygen supply apparatus after leaving the aircraft does not present any major danger to the human body even if the parachute is opened immediately without any time lag.

At altitudes in excess of 8,000 m, jumps without auxiliary oxygen supply are dangerous and, therefore, they are inadmissible (sic!).

For reasons of safety in jumps from altitudes in excess of 8,000 m, the parachute should be opened at altitudes of 3,000-4,000 m.

In addition to the effect of pronounced oxygen starvation during prolonged descent from a high altitude, the parachutist is also exposed to the effects of low temperatures.

Oxygen supply during the parachute descent is ensured by means of the parachute-borne oxygen apparatus type KP-23. This oxygen apparatus ensures the supply of oxygen to the human body at altitudes up to 13,000 m.

Good knowledge and skillful use of emergency rescue equipment during emergencies in the air ensure complete safety of the crew at high altitudes.

CHAPTER IX /153

FLIGHTS UNDER ADVERSE METEOROLOGICAL CONDITIONS

Flights during the day in good weather do not usually present any particular difficulties. However, difficulties may arise during flight through clouds, fog, during rain and snowfalls as well as on dark nights when the pilot cannot see the usual reference marks on the ground and in the sky to which he is accustomed. Such flights are referred to as flights under adverse meteorological conditions. Flights under adverse conditions are of enormous economic and military importance, primarily because poor weather and darkness are no longer a barrier to flying and by flying during such periods continuity of flights is achieved. Secondly, clouds, fog and night darkness are an excellent means of evading discovery during operational missions. Flights under adverse conditions can be sub-divided into flights by instruments and night flights.

Flights by Instruments

Flight by instruments is designated as a flight under conditions of limited visibility of the horizon and terrestrial and celestial reference marks. Flights through clouds, rain, snowfalls, fog, etc., belong in this category.

As regards the physiological features of flight by instruments, it is necessary to make a few general remarks relating to the orientation of man in space.

It is known that in an external medium, man orients himself by means of perceptions which represent reflections of the individual features of the real objects. The joint effect of all the perceived properties of these objects permits correct orientation in the real /154
world and realization of the quality of the objects and their spatial disposition.

With close collaboration of all sensory stimuli: of motion, touch, smell, signals from internal organs and the vestibular system, taste hearing and vision, man orients himself in the external medium. These stimuli are interpreted in the cerebral cortex and produce the corresponding reaction of one type or another.

Of leading importance in this complex physiological process is undoubtedly the visual analyzer. In a complicated complex of stimuli emanating from the visual analyzer, the cerebral cortex first analyzes and then synthesizes the impulses. This is expressed by the visual perception of an object, its position and its movements.

In addition to the visual analyzer (vision), the following participate in the formation of a spatial perception: vestibular system, muscle perception (which can be considered as a device for perceiving the position and movement of the body), as well as the tactile analyzer.

When man is on the ground and there are no barriers to the functioning of the visual analyzers in the form of low illumination of the surrounding medium, it is possible to determine relatively easily the position in space of one's body. This art of orienting himself in space, man acquires from his early childhood and develops during his entire life, depending on the type of activity and conditions under which he lives and works.

If the visual analyzer of man loses for a certain time its leading role in perceiving the position and movement of a body in space, then the importance of the vestibular analyzer and of muscular perception increases; these two enable coordinating correctly the real and the apparent vertical axis and, as a result, determine the position of a body in space. The situation becomes more complicated when the experienced gravitational effects are outside their usual limits.

It is also known from physiology that after eliminating the action of a stimulus of an organ, after-effects occur in the form of an attenuating change of the activity of the sense organs. This can be observed during excitation of the vestibular analyzer. Although this phenomenon may not be of great importance at ground level under normal /155 conditions, during flight it may become the source of a whole number of intolerable complications when evaluating the position and movement of a body in space.

The actions of a pilot in flight aimed at maintaining the desired position of the aircraft in space are much more complicated than, for instance, the actions of a sportsman or a cyclist. They are more complicated as regards their psychological nature, however the physiological senses of these natural mechanisms, by means of which man orientates himself in space, are the same as in the case of a sportsman who walks along a beam, a cyclist who travels along a street as well as a pilot who flies an aircraft. A person can determine quite easily the position of his body in space when sitting on a stool with his eyes closed, or get up with his eyes closed, and turn right or left, since the perception of the vertical axis under these conditions is not influenced by the changes in gravitation which confuse perception of the real position of the vertical axis in a person. The latter effect is achieved as a result of the main participation in these processes of the vestibular apparatus and muscular senses, since the participation of the visual analyzer was excluded in this experiment (the eyes were closed).

In the past, some foreign and Soviet investigators have attemped to devise a theory on the possibility of performing flights without the visual perception of the required reference marks, which enable man to perceive the location of the real vertical axis, on the basis of vestibular reactions and of muscle perception during changes in the position of the aircraft and consequent changes of the position of the pilot's body in the air. All these proved unfounded.

Without visual perception of the appropriate reference marks which enable judging the position of the real vertical, nobody can fly.

The vestibular stimuli and the changes in the direction of the skeletal muscles are obviously inadequate for correct synthesis of the perception of the position of a body in space during flight in the cabin of an aircraft. On the other hand, vestibular stimuli and signals from the striated skeletal muscle system may in many flight situations be a source of erroneous perceptions which disturb the synthesis of the perception of the real position in space and the direction of movement.

Under ordinary conditions of flight, when vision participates in the pilot's perception of his location in space, loss of orientation in space can hardly occur. This situation does, however, occur when the visual analyzer (vision) of the pilot suddenly meets difficult conditions (entering into clouds) or when the pilot, flying from the start by instruments, meets a number of factors which disturb the coordination of the basic nerve processes for one reason or another. If, in addition, there are unfavorable factors in the form of a disturbed cycle of work and rest of the pilot, etc., then, during flight under adverse meteorological conditions, erroneous perception of the location of the aircraft may occur. /156

Experiments have shown that orientation during flight by instruments depends to a large extent on becoming accustomed to reading the instrument panel. This habit has to be developed during training on the ground and in aircraft. On the quality of reading the instrument panel depends the mastering of the technique of piloting under adverse meteorological conditions.

Thus, it can be concluded that the physiological basis of orientation of man in space under various conditions remains the same. Flight by instruments differs from ordinary flight inasmuch as it is performed not by identifying the usual reference marks but indirectly (through a system of intermediate signals read off the instruments). Although there is no particular difference in the physiological components from the point of view of orientation of the position in space, psychologically a number of new conditions arise which complicate perception of the position in space, particularly during the first stages of mastering these types of flights.

When flying by instruments, one has to be guided by their readings and not trust one's senses. The so-called "flight sense" which is developed during ordinary flights may prove deceptive during flights when neither terrestrial nor celestial reference marks are visible. It may also be the forerunner of accidents.

Flight by instruments requires more effort and energy from the pilot than ordinary flight. The feeling of fatigue during flights by instruments can be observed in pilots even in good weather. Most frequently this fatigue is expressed by the fact that without noticing it the pilot begins to make piloting errors; he goes off course, fails /157 to notice rolling, becomes sluggish, apathetic, sleepy, etc. All these are consequences of unusual conditions of piloting and great tension, since in the case of flying by instruments the pilot must observe simultaneously the functioning and the readings of an enormous number of all types of instruments and equipment. That is why it is extremely important to make a correct and rational layout of the instrument panels and in other places in the cabin.

In addition to correct placing of the instruments, it is necessary to ensure that the pilot has a convenient position in the cabin; if his seat is badly placed he may get various erroneous impressions when flying by instruments, which divert from the fulfillment of his task.

Badly fitting clothing, which during ordinary flight may be only slightly inconvenient, may be a source of acute discomfort, impeding the correct piloting of the aircraft when flying by instruments.

When flying blind, conditions arise for all types of erroneous perceptions (illusions) with respect to orientation in space. These may assume a multitude of forms and they greatly impede correct perception by the pilot of the real position of the aircraft in space. In some cases these illusions become so intensive that the pilot will no longer trust the readings of the instruments. Loss of confidence in the instruments may lead to non-fulfillment of the task, with all possible consequences including accidents. The distrust of instrumental readings by the pilot appears to be due to the fact that the unusual situation (without seeing the earth or horizon) in which he finds himself does not bring about the necessary coordination of the sense organs which generate the spatial perception.

Furthermore, under the influence of ground and flight training of the pilots, a new coordination will be established between the sense organs, as a result of which all the false sensations are quickly corrected and the real location of the aircraft in space, is re-established.

The erroneous perception of the pilot during flying by instruments is a result of excitation of the vestibular apparatus by the slight accelerations or by upsetting the coordination in the activity of the visual organ and the vestibular apparatus. The central nervous system plays a leading role in forming erroneous perceptions in flying personnel who are inside the closed cabin of an aircraft or surrounded by clouds. /158

If the pilot has not had sufficient experience in flying by instruments, he will have erroneous perceptions which do not reflect correctly the real position of the aircraft in the air. These illusions include such things as: sensation of counter-rotation when slowing-down or stopping the rotation of the aircraft; sensation of false rolling; sensation of falling (dip) or climbs of the aircraft. Untrained pilots have the illusion of turning in the opposite direction during actual flight by instruments or during flights with the "instrument flying hood" (used for training) in the following circumstances:

- after pulling out of a long turn;
- after pulling out from a spin;
- after getting into and pulling out of a sharp turn.

Such illusions may occur at the beginning of training in instrument flying, after interrupting such flights, and most frequently during prolonged flights when the pilot begins to feel tired. The first manifestations of the illusions bring about such a strong desire to actuate the control rudders to the opposite position that the pilot sometimes has difficulty in resisting it.

When the pilot has mastered the basic concepts of flying by instruments, all these illusions disappear or become less frightening. Even if sometimes he does have a sensation of counter-rotation or "false rolling", the pilot still guides the aircraft by instruments, without being worried by his sensations.

Erroneous perceptions of the position of the aircraft in space, coming from the vestibular system, represent the normal physiological reactions which are perceived more clearly because the pilot is under specific conditions of flight - without seeing the landmarks to which he is accustomed. Flight by instruments primarily impedes the use of visual perception for coordinating the movements in accordance with terrestrial landmarks when determining the position of the aircraft during flight and it is as a result of this that the air crew have erroneous sensations. Everyone has them but in varying degrees. Most of the crew of fighter aircraft have these erroneous sensations for no longer than 5-6 seconds. However, in the case of untrained air crews or pilots who have not flown by instruments for a long time, these sensations last 12-18 seconds. This has to be taken into consideration during /159 training on the ground and in the air. If a pilot does not fly by instruments for 6 months or longer, he will again be subject to erroneous sensations which earlier had ceased altogether or were only slightly pronounced owing to cabin training and flights under cloudy conditions. Frequently these erroneous representations are not of a clearly defined nature and cease after a few flights.

Thus, after interruption for a certain period of time, the earlier acquired correlation in flights by instruments, are re-established faster than in the case of untrained pilots.

If flights by instruments are interrupted for a period of some years, the pilot should undergo careful training prior to renewal of such flights. In spite of the fact that they were well trained in a hooded cabin, the aircrews will again be subject to erroneous perceptions during flight under cloudy conditions and during actual penetration of clouds, although they were not subject to such illusions prior to penetrating the clouds. However, these phenomena are not permanent and after two or three flights under cloudy conditions they are suppressed by will-power and subsequently cease altogether.

Various disturbances in the air (lightning discharges or radio failures) which produce crackle and noise in the headphones, either increase the intensity of erroneous sensations or may cause their reappearance and, in some cases, also dizziness. During flights by instruments, in addition to physiological illusions (counter-rotation) there will also be psychological illusions which complicate still further the flight and continue to give misleading notions regarding the position of the aircraft in space. The persistence of these illusions depends to a great extent on the physical condition of the pilot. They may become intensified after drinking alcohol, excessive smoking, nervous and psychic stresses, over-tiredness, after sickness and if the pilot has not adhered strictly to a regular work and rest routine.

To prevent these illusions, measures are recommended aimed at reducing the unfavorable influence of factors which cause their appearance. These measures are: systematic training on ground-based trainers and special mock-ups; systematic flight training in instrument flying; adhering closely to a sequence of flight training rules under adverse meteorological conditions; adhering to a correct schedule of work, rest and diet; systematic physical training and sporting activities, particularly of the types which train the vestibular apparatus, the heart, blood /160 vessels, nerve and muscle systems. Of the illusions relating to the position of the aircraft in space which are usually observed only during flights by instruments, we distinguish between various visual illusions: visual illusions from light marks when stars are mistaken for navigation lights; lights on the ground are mistaken for stars, etc.

During flight in clouds and fog, light flashes appear on the illuminated part of the cabin, or light spots on the clouds from the headlights of the aircraft or searchlights, and these can bring about visual illusions of barriers or apparent changes in the position of the aircraft in space.

Illusions are also formed when observing landing lights from a great distance - for instance, the illusion of greater height, distortion of the perception of shape of objects outside the aircraft, and difficulty in determining their distance. These difficulties occur as a result of changes in the refraction of the light beams which pass through rain, snow, clouds and fog.

Night Flights

In practical aviation, night flights are very frequent; they have become as frequent as day flights. By night flight, we understand a flight under conditions of twilight or under night illunination, when the visibility of the earth surface is low. Flying is basically by instruments, using artificial illumination of the instrument panel by means of red or ultraviolet light. Night flights are classified as flights under adverse conditions; they have many advantages as compared with day flights but they are more difficult. Flying personnel must be more skillful to perform such flights and they are subject to greater nervous and psychic stresses. Furthermore, night flights require a very complex organization, particularly as regards ground facilities.

Visibility during night flights depends on the overall natural illumination, the degree of cloudiness and the geographical latitude.

The ground cannot be seen very clearly on a dark cloudless night, and during a dark cloudy night the ground and the horizon cannot be seen at all.

It is possible to see during the night such landmarks as lakes and rivers (during the summer) due to their gleam and reflection of light, railroad tracks, highways, forests, inhabited areas and, in some cases, also country roads. Luminous landmarks such as lighthouses, searchlights, ordinary lights, etc., can be clearly seen. /161

The particular features of night flying should be clearly explained to the aircrews, who should be familiar with these features and take them into account in practice.

The human organism has adapted itself, throughout its long evolutionary development, to a certain rhythm of living: working during the day and resting during the night. In accordance with this life rhythm, a certain sequence of physiological processes has developed in the organism. Usually, during night rest the intensity of these physiological processes is somewhat lower than during the day.

The established customary succession of work and rest is frequently upset, not only for aircrews but also for other people who work on night shifts.

Obviously, a changeover to night work has at first an adverse effect and manifests itself to a varying degree on the well-being and work-capacity of the persons concerned.

However, in the case of disturbance in the rhythm of work and rest to which man is accustomed, his body will adapt itself to the new conditions with the progress of time.

A clear example of this is the work of people who live under conditions of polar days and nights. When people start living under these conditions the first days and weeks are accompanied by a drop in their working ability and a jaded feeling, but then they adapt themselves fully to the new conditions. The same phenomena occur in aircrews when they change over to night flying.

It is pointed out that when night flights are carried out it is not the change in the ordinary schedule of work and rest which has the most important influence, but the inefficient utilization of the time scheduled for rest prior to and after the flight. Pilots frequently use this time for other purposes.

During night flights the eyes have to satisfy very exacting requirements.

The difficulty of night flying consists in the fact that under /162
weak illumination it is difficult to see landmarks, objects, etc. This is particularly pronounced in combat when artificial illumination is either switched off or masked.

Furthermore, the poor visibility during night flying is accentuated by the difference between the illumination in the cabin of the aircraft and that of the objects on the ground. The pilot must frequently switch his eyes from the relatively well-lit cabin of his aircraft to the darkness to distinguish poorly lit objects on the ground, and from the darkness back to the illuminated cabin, which adversely affects the adaptability of the eyes.

The performance of the eyes will become appreciably lower under conditions of weak illumination:

- there is a decrease in the acuity of vision (the ability to distinguish details of objects);
- perception of depth becomes poorer (this manifests itself during take-off and landing); pilots have to be specially trained for night flying;
- there is no color perception; during night illumination all colored objects appear gray;
- the field of vision narrows.

The pilot must become adapted to darkness to carry out night flights, i.e., his eyes must adapt themselves to seeing low brightnesses under conditions of darkness.

After one hour in darkness, the sensitivity of the eye may increase to about 200,000 times the initial value.

The sensitivity of the eye to darkness after a bright light increases slowly at first, then more rapidly, and finally more and more slowly. It is considered that about 25-30 minutes are required for adapting the eye to conditions of darkness.

Adaptation of the eye to conditions of darkness proceeds as a result of the automatic regeneration of rhodopsin (visual purple, a photochemical substance) of the rods and the retina which decomposes under the effect of light.

Consequently, adaptation of the eye to darkness is a process of the adaptation of the rods to conditions of weak illumination when there is a regeneration and accumulation of the photochemical substance rhodopsin to its maximum concentration and, as a result of this, the light sensitivity of the eye increases.

When the eye is adapted to darkness it is more sensitive to green light and less to red. Blue and yellow lights assume an intermediate position. /163

In adapting the eye to high illumination intensities, the central depression of the retina becomes the most sensitive spot whereby the yellow-green light appears brightest, while red light will appear least bright.

Due to various processes adaptation during night flying is slower, the acuity of vision decreases and generally there is a decrease in night vision.

For night flights the aircraft should be fitted with rational illumination which enables the pilot to read the map and instruments quickly without impeding his night vision, i.e., the ability of his eyes to see objects outside the cabin under conditions of twilight and night illumination.

We have already analyzed the principles of the pilot's visual processes during night flying, and on this basis the requirements of cabin illumination can be formulated in a more concrete form.

Illumination of the cabin should be such that the pilot should be able to distinguish clearly the illuminated instrument dials without eye-strain and, at the same time, retain his darkness adaptation which is necessary for seeing through the darkness outside the aircraft. It is necessary to point out that the night vision of the pilot is impaired most by the action of rapid changes in brightness. Such changes in brightness cannot be avoided during night flights. During the entire flight the pilot must look at the readings of the instruments in the lighted cabin as well as at landmarks. The illumination in the cabin must permit rapid reading of the instruments without blinding the eye. If the cabin is excessively lit the pilot will have difficulty in distinguishing poorly lit objects and objects on the ground. This is why illumination of the instrument panel in the cabin should be neither too high nor too low. Its intensity should also depend on the degree of darkness of the night.

Normal illumination should be from 0.5 to 10 lux with gradual transition from one intensity to the other.

Usually, illumination is by means of reflected light. It is definitely not admissible that direct rays from the source of illumination should hit the eye of the pilot or that there should be light reflections from the glass of the instruments and lamps. /164

The instrument panels and the dials of the instruments are painted matt black and the walls of the cabin are painted dark gray to ensure the best conditions for visual perception.

One would have thought that the dial scales of the instruments should be painted yellow-green, a color to which the rods of the eyes are most sensitive. However, experiments have shown that during weak illumination of the cabin yellow-green scale division lines cannot be clearly seen. If yellow-green lines are substituted by red ones, the clarity of vision of the lines increases very effectively.

In view of the fact that the twilight vision apparatus (rods) has a low sensitivity to red, the red color combinations do not impede the darkness adaptation of the eye and the vision of the pilot retains a high sensitivity to darkness that he can see satisfactorily objects and signals which are outside the aircraft.

It is necessary to provide general illumination to permit orientation in the cabin. The most suitable for this purpose is diffuse red light, since this does not impede the darkness adaptation of the eye.

In addition to general illumination, local light has to be provided for reading maps, log books, etc., using red lamps.

The lighted-up areas of instruments must not produce a high overall brightness. This brightness can be controlled by illumination with ultraviolet rays from an ultraviolet illumination system.

It is also necessary to provide correct illumination of the rooms where the pilots wait for take-off on night flights. It must be as uniform as possible without any excessive contrast or shininess which would blind the eyes of the pilot. It is highly advisable to provide red illumination in the rooms intended for the aircrew.

All the lamps in the rooms reserved for the aircrew should have shades of a matt finish. Table lamps with shades should be used for the working space, placed near to the pilots.

The pilot must adapt himself to night flying:

- before take-off; /165
- after flying through searchlight beams during approach to the place of landing;
- during landing from high altitudes, taking into account the influence of oxygen starvation.

A reduced or sharply pronounced lack of adaptation of the eye to darkness is closely connected with food intake and particularly with vitamin A deficiency. Vitamin A plays an important role in the regeneration of visual purple (rhodopsin). Therefore, night flying requires particular attention to the diet of the aircrew. It must comprise foods which contain adequate quantities of Vitamin A.

Rest during the day is compulsory prior to night flying.

Strong physical, nervous and psychic exertions, excessively long walks, general tiredness, insomnia, inadequate sleep, effects of bright lights, straining the eyes by bright illumination, consumption of alcohol, exposure to radial accelerations, noise, or cold - all these reduce night vision.

Particular attention should be paid to the oxygen supply. Even during daytime flying, inadequate oxygen intake at altitudes from 2000 - 3000 m upwards lowers the efficiency of the eyes and during the night when the performance of the eyes is considerably weakened due to low illumination, insufficient oxygen in the inspired air will considerably reduce the performance of the eye, even at heights of 1500 m. Therefore, during night flights particular attention must be paid to additional oxygen supply; the oxygen equipment must be switched-on from ground level onwards.

It is necessary to bear in mind that training for night action is of very great importance.

There must be continuous strict medical supervision to prevent night flying by pilots whose eyes do not satisfy the requirements to be met in aviation.

Particular attention must be paid to acuity of vision, color vision and adaptation to darkness.

People with reduced acuity of vision (below 0.8 for each eye), with disturbed color vision and poor adaptability to darkness should not be allowed to carry out night flights.

CHAPTER X /166

TECHNICAL LIQUIDS AND PROPHYLACTIC MEASURES IN HANDLING THEM

In modern aviation extensive use is made of various technical liquids, the handling of which calls for certain prophylactic measures. These include in the first place the so-called aggressive liquids (nitric acid, hydrogen peroxide, xylidine, triethylamine, hydrazine), then tetraethyl lead liquid, antifreeze, gasoline, benzene, kerosene, dichlorethane, technical lubricants and others.

Aggressive Liquids

Fuming Nitric Acid (HN_2O_3)

Fuming nitric acid is widely used in industry; it is a reddish liquid of acrid smell which evolves brownish fumes. Nitric acid fumes are 2.2 times heavier than air. It mixes with water in all proportions with the evolution of heat. It is very hygroscopic and fumes strongly in air evolving nitrogen pentoxide which forms a mist with moist air. Nitric acid is decomposed by light with the evolution of oxygen and the formation of nitrogen dioxide. Nitric acid is a strong oxidizing agent.

Liquid nitric acid can ignite organic materials (such as wood or clothing) with which it comes into contact.

An explosion may occur when nitric acid comes into contact with kerosene, gasoline, lubricants, alcohol, turpentine, etc. The fumes of nitric acid irritate the respiratory system. This effect is appreciably intensified if certain aerosols are also present in the air. /167

Inhalation of nitric acid fumes can even destroy the teeth, mucous membranes and corneas of the eye. In experiments on animals (cats) it was found that there were no serious consequences when the animals were left for 2 1/2 hours in an atmosphere with a concentration of nitric acid fumes of 0.2 mg/liter. Exposure to an atmosphere of 0.3 mg/liter nitric acid fumes for 2-3 hours causes serious damage, and a concentration of 0.5-0.7 mg/liter can be fatal even with short exposure.

Autopsy of the affected animals reveals acute damage to the respiratory tract, hemorrhage, and edema of the lungs.

The inhalation by humans of air containing nitric acid fumes, even at low concentrations, causes irritation of the mucous membranes of the respiratory ducts. Exposure of the eye to nitric acid fumes causes pain and tear formation.

Prolonged exposure to nitric acid fumes at concentrations of 0.05-0.07 mg/liter causes headaches, dizziness, noise in the ears, weakness, and at higher concentrations edema of the lungs.

Nitric acid in the liquid-drop form burns the skin; repeated exposure to dilute acid promotes chronic damage to the skin. On entering the blood, nitric acid causes general poisoning of the organism.

The limiting permissible concentration of nitric acid fumes in the air of workshops is at present considered to be 0.005 mg/liter (Standard GOST1324-47 - Sanitary Standards for the Design of Industrial Premises.).

Hydrogen Peroxide

Hydrogen peroxide (H_2O_2) is widely used in industry. It is a liquid of bitter-astringent taste without color or smell. It mixes with water in all proportions. It is easily decomposed into water and oxygen. Because of its ability to evolve oxygen it is a very strong oxidizing agent.

Hydrogen peroxide vapors irritate the mucous membranes of the eyes and respiratory ducts; prolonged exposure to the vapors can cause diseases of the lungs and internal organs. /168

With careless handling, constantly working with concentrated solutions of hydrogen peroxide can frequently lead to inflammation of the skin and even burns.

If hydrogen peroxide at high concentration (over 70%) comes into contact with organic materials they ignite.

It is considered that the maximum permissible concentration of peroxide vapor in the air is 0.01 mg/liter .

Xylidine

Xylidine is a liquid with a characteristic unpleasant smell. It can enter the human organism through the respiratory ducts in the vapor form, in the liquid condition by acting on the skin, and also by entering the alimentary canal. Whatever the mode of entry, xylidine is quickly absorbed by the blood and distributed throughout the organism by the blood circulation, having a toxic effect. The first effects are observed in the nervous system, liver and blood. Poisoning may be acute or chronic. In cases of acute poisoning there is usually cyanosis of the mucous membranes, teeth, face, ears and finger tips. There then occur headache, dizziness, weakness, and sometimes vomiting. In severer cases there is cramp and loss of consciousness. Derangement of the functions of the central nervous system is often observed (acute excitement, changing to fatigue, sleepiness and inertia). The functioning of the heart is disturbed. Depending upon their intensity, the symptoms of poisoning last from 3-5 up to 15-20 days.

The poisoning symptoms are not so strongly marked in chronic poisoning. There is gradual development of derangement of the functions of the central nervous system, expressed in sleepiness; then changes occur in the blood, with loss of appetite, weakness, etc., and, after a few weeks, jaundice develops. Death can occur a few days after the occurrence of jaundice.

For prolonged working, the maximum permissible concentration of xylidine vapors in the air is at present considered to be 0.005 mg/liter.

Triethylamine /169

Triethylamine is a liquid of unpleasant smell. The substance can enter the organism either in the vapor form through the respiratory ducts or through the effect of liquid on the skin. On entering the blood stream, triethylamine poisons the organism. The toxic effect of triethylamine first affects the central nervous system, the lungs, heart, liver and other internal organs.

Symptons of triethylamine poisoning are excitement, general weakness, headache, paleness of the skin and mucous membranes. Autopsy of animals exposed for various periods to atmospheres containing triethylamine vapors reveals that the lungs, liver, kidneys and other internal organs are overfilled with blood and there is also hemorrhage in them.

If the exposure of the animals has continued for several weeks, in addition to the above, there are pronounced regions of degeneration in the heart, liver and kidneys.

Numerous small ulcers form on the mucous membranes of the eyes and the cornea, and the eyes run.

This kind of damage to the eyes is also sometimes observed in people who work with triethylamine. Triethylamine causes noticeable irritation of the skin.

The maximum permissible concentration of triethylamine vapors in the air is considered to be 0.005 mg/liter.

3

Hydrazine

Hydrazine is a pale yellow oily liquid of unpleasant smell. It is a strong reducing agent and a very strong poison which can cause decomposition of the red and white blood corpuscles. It can enter the organism through the respiratory tract or the skin.

The symptoms of hydrazine poisoning are as follows: in light cases - headache, paleness, loss of appetite, diarrhea and stomach ache. Recovery occurs after a few days. In more severe cases there is dizziness, shortness of breath, flashes in the eyes, twitching of the eyes and tongue, acute anemia. Complete recovery takes two or three months. Severe poisoning can be fatal.

Systematic exposure of the skin causes eczema. The eczema sometimes extends all over the body and is accompznied by severe itching and general disorder.

Prophylactic Measures in Working with Aggressive Liquids /170

Persons working with aggressive liquids may be affected in the following circumstances:

(1) During the transportation and storage of the liquids in open vessels because, under these conditions, they evaporate and moreover, accidental spilling on clothing or the work place is possible.

(2) During fueling operations on aircraft, draining of fuel systems, pouring constituents from tanks and during the dismantling and erection of sets of aircraft equipment. Severe poisoning and damage to the skin may occur in the absence of special clothing and individual means of protection. Burns may be caused by the ignition of clothing when it comes into contact with nitric acid or hydrogen peroxide.

(3) In carrying out service work on the fueling systems where the sets and systems are inadequately sealed.

(4) In filling tanks and in measuring out fluids in stores without using individual protective measures.

(5) In cases of accident causing damage to communication lines, tanks and sets of equipment.

The following prophylactic measures are necessary to prevent harm to people working with aggressive liquids.

4

(1) All personnel who come into contact with aggressive liquids should be provided with modern industrial type gas-masks, unbreakable glass goggles, industrial type leather and rubber gloves, cloth polyvinylchloride or rubber footwear, 'textovynite' (Note: Presumably cloth-reinforced vinyl plastic) overalls.

In winter, all the staff must have woolen gloves to wear under the rubber ones and linings of warm material to wear under masks, fur leggings and fur combination suits.

Wherever work with aggressive liquids is carried out there should be a spare set of protective clothing for rapid changing in cases of accident, resulting in damage to the set of protective clothing which is in use.

Special premises should be provided for the storage of special /171
clothing and individual protective equipment, which should not be removed.

If fuming nitric acid or hydrogen peroxide comes into contact with protective clothing, the affected part must be immediately washed with large quantities of water and the protective clothing removed.

If clothing becomes contaminated with xylidine, triethylamine or hydrazine, it must be degassed in steam equipment.

Working with aggressive liquids is categorically forbidden in the absence of special protective clothing and special premises for its storage.

(2) Bays for jet aircraft should be smooth and made of acid resisting concrete.

To promote rapid removal of water on washing the floors, they should be made with a slight slope to drain the water into a neutralizing sump.

Water supplies must be provided to all places and premises where work with aggressive liquids is carried out so that a powerful jet of water can quickly be applied.

All enclosed premises must be provided with effective injection and extraction fans to ensure the necessary rate of air exchange for rapid removal of harmful substances from the premises. Air intake for injection systems of ventilation should be taken from uncontaminated atmospheric zones as high as possible above the ground surface.

Special premises are provided for liquid storage in which the storage of other materials and articles is forbidden.

The liquids should be transported in special vessels on vehicles especially designed for this purpose by a suitably qualified staff.

All work with the liquids (charging into aircraft or transferring from one vessel to another) must be done mechanically in a closed system.

Bays for jet aircraft, handling equipment and fuel storage premises should be not less than 1,000 meters away from living and domestic quarters.

The repair of equipment and tankage is permitted only after careful water washing.

Not less than two persons should work together on aggressive liquids. After working on poisonous liquids, all persons who have come into contact with them should wash in a shower of hot water using soap. /172

Persons proceeding to work where they may come into contact with aggressive liquids are subjected to a careful medical certification in order to reveal if the condition of their health is such as to make them unacceptable for work of this nature.

Thereafter, as a prophylactic measure, all persons occupied in such work are subject to regular medical examination not less than once in three months. To ensure completely safe working with aggressive liquids, all persons permitted to work with these liquids first receive instructions. The instruction provides for detailed familiarity of the staff with the toxic properties of the liquids and conditions which may be the cause of harm to persons.

Besides this, practical work is carried out to teach the staff self and mutual aid in cases of exposure to these substances and also to acquire familiarity with the use of the individual protective measures and the practical fulfillment of the observation of safety measures. After instruction and carrying out special practical work, the students are examined within the scope of the current instructions issued to ensure safety of the staff when working with poisonous and corrosive liquids.

First-Aid Measures for Effects of Aggressive Liquids

Effects of Nitric Acid.

On being affected by nitric acid fumes, the affected person should immediately quit the contaminated section, wash the eyes and gargle with a 2% soda solution.

In cases of difficult breathing and acute irritation of the mucous membranes, the affected person must be immediately transferred to medical treating premises for treatment and observation of his health.

When affected by liquid nitric acid it is necessary immediately to wash copiously the affected parts first with a jet of water and then to wipe the parts with swabs moistened with 2-3% soda solution. /173

If considerable areas of skin are affected the patient must be immediately transferred to premises for medical treatment.

Effects of Hydrogen Peroxide.

On exposure to hydrogen peroxide vapors, it is necessary to wash the eyes and throat with warm water and then to wash the eyes and gargle with a 2% soda solution.

On coming into contact with liquid hydrogen peroxide, the saturated clothing must be quickly removed and the affected parts must be immediately washed with large quantities of water. After this, it is recommended to use lotions of Goulard (leaded) solution.

Effects of Triethylamine and Hydrazine.

Persons affected by these substances in the gaseous condition should be immediately removed from the poisoned atmosphere, given complete rest and sent to medical premises for observation and treatment.

If affected by these substances in the liquid condition, the clothing contaminated by the liquid must be immediately removed, the affected places should be washed with water and the patient should be sent to medical premises for treatment.

Liquid Tetraethyl Lead. (TEL).

For normal operation most modern internal combustion engines require fuel of good anti-detonating properties. The most commonly used method of improving the anti-detonating properties of fuels is by the use of anti-detonating additives. The most effective such additive known is liquid tetraethyl lead (TEL) which is incidentally a highly toxic substance.

TEL is very volatile. A considerable vapor concentration is easily formed in air even at temperatures below freezing. TEL is easily soluble in organic liquids such as gasoline, kerosene, ether, chloroform and also in fats. The ease with which TEL is absorbed is of great importance. It has been shown that plastering, ground, and timber materials easily absorb TEL which becomes difficult to remove. /174

To improve the anti-detonating properties of aviation gasoline there is added to it from 0.75 to 4 cm^3 of TEL per kilogram of gasoline. Leaded gasoline is produced in this way. Leaded gasoline is of great economic importance. Therefore, despite the high toxicity of TEL , leaded gasoline is widely used and will continue to be used until another anti-detonating additive has been discovered, which is as effective as TEL but less toxic.

The toxicological properties of TEL fluid and leaded gasoline result from the presence of tetraethyl lead. Accordingly, cases of poisoning with these substances must be considered as poisoning with tetraethyl lead. Accordingly, cases of poisoning with these substances must be considered as poisoning with tetraethyl lead. Tetraethyl lead can enter the organisms through the respiratory ducts as vapor, through the skin in liquid form and as vapor and also through the alimentary canal as a result of accidental ingestion of TEL fluid or leaded gasoline. The risk of poisoning is more severe because ordinary local poisoning effects are not observed on coming into contact with these products. There is first a period of concealed poisoning which in humans can last from some hours to some days. Numerous observations have shown that even persons who have been heavily poisoned with these substances do not suspect the presence of poisoning for a certain period of time.

The absence of local irritation and the period of concealed action sometimes lead to thoughtless handling of TEL fluid and leaded gasoline; technical staff often use leaded gasoline for cleaning and even washing uniforms, washing hands, filling lighters, lighting soldering irons or for washing various parts, etc. Neglect of the rules for handling TEL fluid during transport in inadequately sealed vessels, storage in open vessels, spillage on the floor in gasoline stores and on the ground around them, working without special protective clothing, neglect of degasification, etc., all these can lead to serious consequences.

The selective action of tetraethyl lead on the central nervous system governs the specific features of poisoning by this substance. /175

Poisoning may be acute or chronic depending upon the nature of the affectation. As TEL has highly cumulative properties, the risk of chronic poisoning is possible in all cases where TEL fluid or leaded gasoline is handled. This circumstance calls for systematic work to prevent poisoning by these products.

Acute poisoning. Acute poisoning occurs when substantial amounts of tetraethyl lead enter the organism.

Duration of the concealed period of poisoning depends upon the quantity of poison, the method of ingestion and also on individual characteristics of the organism.

Acute poisoning is classified as light, medium or severe according to the degree of affectation. It should be noted that when TEL enters the organism through the stomach the signs of poisoning occur very quickly. In this case disturbance of the functions of the central nervous system occurs first of all.

Light poisoning. With small amounts of poison, there is frequently observed marked slowing of the pulse, reduction in blood pressure and body temperature, and somewhat increased sweating and salivation. These effects are soon accompanied by headache and disturbed sleep. Sleep becomes superficial, restless, with shuddering and bad dreams. In most cases all these symptoms are reversible and do not cause loss of work.

Poisoning of medium severity is characterized by clear symptoms of reduced temperature (to 36-35°), low blood pressure (to 90/50 mm), slowing of the pulse to 45-60 beats per minute. Disturbance of sleep becomes more severe (prolonged dozing or sleeplessness). Tremors are observed in the eyelids, the tongue and in the extended fingers.

Reduction of intellect is frequently observed with loss of memory, loss of discrimination and severe fatigue under mental stress. These symptoms may be accompanied by excitation with an uncritical attitude to one's own condition, disturbance of bodily equilibrium, the feeling of a foreign substance in the mouth (most frequently hair).

If the poison directly enters the stomach, there is observed nausea, vomiting, and pain in the substernal region. The course of poisoning is more severe. /176

If there is acute disturbance of sleep, with sleeplessness accompanied by feelings of alarm and confusion with hallucinations of hearing, feeling and smell combined with an insufficiently critical assessment of the patient's own condition, then the condition borders on severe forms of poisoning, and the patient must be provided with special hospital treatment.

Severe poisoning is characterized by loss of orientation, confusion of consciousness, restlessness, excitement, abundant hallucinations of vision, hearing and smell, and intellectual breakdown, i.e., acute toxic psychosis. Death often occurs on the borders of nervous breakdown. If the outcome of severe poisoning is favorable, treatment is usually prolonged (6 to 12 months or more). Psychic disturbances frequently appear unexpectedly; however, severe psychic disorders are invariably preceded by a period, which may be short, of preliminary symptoms, above all disturbances of sleep and hallucinations of touch.

Chronic poisoning can result either from prolonged ingestion into the organism of small quantities of tetraethyl lead or as the result of repeated light poisoning, often not recognized in time.

The most typical fundamental symptoms of chronic tetraethyl lead poisoning are: reduction of blood pressure (90/50-85/40 mm Hg); slowness of the pulse (to 55-45 beats per minute); reduction of temperature (below 36°); increased salivation; perspiration; rapid fatigue; general weakness; reduction of activity; tremors of the hands, eyelids and tongue; headaches, which recur periodically and soon pass; disturbed sleep, particularly during the period of going to sleep; paleness of the skin; sometimes loss of weight and change of intellectual activity (impaired memory, grave instability of disposition, marked touchiness, frequent marked excitability, etc). However, in chronic poisoning, multiple symptoms are rarely encountered; they usually appear singly. The clinical picture of chronic poisoning usually develops gradually over a long period of time and depends on the quantity of poison entering the organism and the individual characteristics of the organism. /177

In most instances, light cases of chronic poisoning pass off without loss of ability to work; cases with disturbances of the intellect, emotion, and will are more severe and may be accompanied by reduced ability to work.

Prophylactic Measures. Wherever workers come into contact with TEL, even in small amounts, steps must be taken to prevent occupational and non-occupational poisoning.

All persons who start work associated with the use of TEL fluid and leaded gasoline should receive a preliminary medical examination, the object of which is to exclude from the work persons with unsatisfactory health symptoms. Compulsory medical examinations are periodically made to ensure early recognition of the initial symptoms of poisoning and to ensure that the necessary prophylactic steps are taken. Persons who are commencing to work with TEL fluid or leaded gasoline should be instructed carefully and in detail about the safety rules and also about the danger of using TEL fluid and leaded gasoline for domestic purposes. The instruction must be documented and repeated every three months.

All persons working with TEL fluid and leaded gasoline should be taught safe methods of working and special precautionary measures.

Work with TEL Fluid

During transport, drums of TEL fluid should be accompanied by experienced, specially instructed persons, to supervise the loading and unloading work, to ensure the drums are properly sealed and that the means of transport are degassed after use. TEL fluid may be transported only in containers sealed at the works and the transport of TEL fluid together with any other goods, and above all, with persons is categorically forbidden. The transport of drums of TEL fluid or leaded gasoline in automotive vehicles with enclosed bodies is permitted only /178
on specially equipped machines, the deck and sides of which are covered with sheet steel with soldered or welded joints, as it is almost impossible to degas wood which has become contaminated with TEL. It is dangerous to store TEL fluid together with any other substances because they may become contaminated. The floors and walls of the store should be made of materials which do not absorb TEL and which can be degassed and washed (iron, concrete, metal, etc.); constant exchange of the air should be provided in the premises. In storing drums of TEL fluid in the open air, special concreted areas should be provided with a covering of iron and raised edges.

In places or premises where gasoline is mixed with TEL fluid, strict sanitary conditions must be established and degassing conducted systematically. In all these places working in private clothing is forbidden; it is essential to wear special clothing consisting of personal linen, a cotton combination suit, rubber knee boots, a polyvinylchloride apron which should also cover the chest, oversleeves, rubber gloves and gas mask.

The procedure for storage and delivery of leaded gasoline should prevent the possibility of its being used for other than the intended purpose and in particular the use of leaded gasoline in domestic equipment must be prevented.

Repair of tanks and vessels for leaded gasoline requires particular attention; it can be carried out only after traces of leaded gasoline have been removed or after degasification.

The requisite precautions must be taken when working in storage tanks and the like, such as working in a gas mask with air supply through a hose, presence of a watchman, provision of means for getting the worker out in case he loses consciousness, etc.

At airports, engine operators and aviation technicians come into contact with leaded gasoline as well as stores' staff; flying staff are usually little in contact with fuel.

The main precautionary measures in handling leaded gasoline at airports are as follows: aircraft should be fueled from the windward side and fueling should be performed carefully without spillage onto the ground or the machine. If gasoline escapes accidentally, immediate steps /179 should be taken to remove it. In this case, it is best to use a solvent (kerosene). Personal prophylactic measures are the same as those described above: the use of special gloves, washing hands in kerosene and hot water with soap. Means for degasification should be close to the working place so that in cases of contamination of hands, clothing or equipment, degasification can be carried out immediately.

Provision of First Aid. If TEL fluid comes into contact with clothing, it must be immediately removed and parts of the skin contaminated with TEL fluid should be treated with wads of cotton wool moistened in kerosene or pure gasoline and then carefully washed with soap and water. If for any reason the TEL fluid has been ingested, vomiting must be caused. After first aid has been applied, the patient must be sent to a medical treatment establishment.

Antifreeze

Antifreeze is a liquid the composition of which includes ethylene glycol and water. It is used as a fluid of low freezing point.

Poisoning with antifreeze may occur as a result of its ingestion, mainly through the alimentary canal.

Clinical observations have established that if a human being takes in up to 50 cc of antifreeze, light poisoning occurs resembling intoxication; up to 100 cc causes medium poisoning; up to 150-200 cc, severe poisoning and 400-500 cc or more cause fatal poisoning.

In the alimentary canal antifreeze is rapidly absorbed and causes intoxication, usually with noticeable depression of the action of the central nervous system and after a certain time it is noticed that the liver and kidneys are affected by the decomposition products of ethylene glycol, which can result in a fatal outcome. In severe cases death may also occur during the period of intoxication owing to paralysis of the respiratory center.

Prophylactic measures are required to prevent poisoning by antifreeze. Above all, extensive use should be made of explanatory work among the staff who come into contact with antifreeze during the course of their work. Similar educational work should also be carried out /180 among other categories of specialized military units because poisoning often results from ignorance.

The most important thing is to prevent antifreeze from entering the alimentary canal. Moreover, in working with antifreeze it is necessary to prevent its vapors from accumulating in the working premises and also the wetting with it of leather coverings and clothing.

In cases of antifreeze, poisoning first aid consists in immediate removal of the product from the stomach by causing vomiting. If possible, the patient should be given oxygen to breathe. Moreover, in winter, care must be taken to keep the patient warm and, in summer, to avoid overheating. After first aid has been applied, the patient should be sent to medical premises for treatment.

Gasoline

Gasoline is a transparent volatile fluid the composition of which includes hydrocarbons, paraffins, naphthenes and olefins.

In modern aviation, gasoline in the pure form is rarely used. Being a good solvent, pure gasoline is widely used in aviation repair workshops, and at airports for washing various parts and for other purposes.

When working with gasoline in enclosed and badly ventilated premises the surrounding air soon becomes saturated with gasoline vapors and in a short time, their concentration in the air may become dangerous. Air is considered safe for human health only if the amount of gasoline vapor in it does not exceed 0.3 mg per liter. Acute and chronic poisoning may occur at higher concentrations of gasoline vapor.

In aviation sections, cases of harmful effects of gasoline on the organism may result either from breathing its vapor or from contact with the skin. When gasoline enters the organism through the respiratory tract, it can cause acute and chronic poisoning. Acute poisoning by gasoline can occur even after brief (a few minutes) breathing of air containing gasoline at a concentration of 5-10 mg per liter. Chronic poisoning occurs on prolonged exposure of the organism to low concentrations.

Poisoning of various degrees can occur in cases when precautionary /181 measures are not taken: when working with gasoline in enclosed poorly

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ventilated premises, during cleaning and repair of gasoline tanks, and drums; during slipshod fueling of aircraft.

In both acute and chronic gasoline poisoning the central nervous system is damaged.

In cases of acute poisoning there occurs dizziness, headache, weakness, generally excited condition, nausea and vomiting. At gasoline vapor concentrations of 50-85 mg/liter, rapid loss of consciousness may occur and a fatal outcome can be avoided only by providing immediate assistance to the patient. In cases of chronic poisoning, there are observed periodic headaches and dizziness, increased irritability, disturbance of sleep and loss of appetite, increased perspiration, anemia and weakening of cardial activity. In addition to the generally harmful effects of gasoline on the organism, mention must be made of its unfavorable local effects. Being a good solvent of fats, gasoline degreases the skin, causing it to dry out and crack, which promotes the development of festering infections of the skin. Moreover, systematic washing of the skin with gasoline is one of the causes of significant propagation of inflammatory processes, and eczema of the hands in aviation engine mechanics, aviation technicians and the staff of aviation repair workshops.

A number of measures must be taken on aviation sections to prevent the harmful effects of gasoline on the organism:

- the harmfulness of gasoline to the organism and the need for prophylactic measures should be systematically explained to the personnel of aviation sections and aviation repair organizations;

- separate injection extraction ventilation systems should be installed in all premises where gasoline evaporates;

- the use of gasoline for hand washing should be forbidden;

- all persons working with gasoline should be systematically and thoroughly medically examined not less than once every three months.

Provision of first aid. In cases of acute poisoning the patient must be removed from the contaminated atmosphere to pure air. If there are symptoms of excitement valerian drops should be given until the doctor arrives. /182

In severe cases with marked weakening of breathing or the occurrence of fainting, the patient should be given ammonia to smell and pure oxygen should be applied. If breathing has ceased, artificial respiration must be applied at once.

Benzene

Benzene is the simplest compound of the aromatic class of hydrocarbons. In appearance it is a transparent colorless volatile liquid with characteristic taste and smell. It is a good solvent of fats, resins, rubber, sulphur, phosphorus iodine and other substances. Benzene is a strong poison several times more toxic than gasoline.

In aviation practice, benzene is widely used as a component part of aviation varnishes and as a solvent in carrying out various kinds of work.

Because of the high volatility of benzene its vapors can soon reach dangerous concentrations in enclosed badly ventilated premises. The maximum permissible concentration of benzene vapors in the air is considered to be 0.05 mg per liter. Higher concentrations can cause acute or chronic poisoning.

With a benzene concentration in the atmosphere of 10 mg per liter exposure for about one hour causes light poisoning, at a concentration of 20-25 mg per liter exposure for the same period can cause dangerous poisoning; at benzene concentration of 60-65 mg per liter five-ten minutes exposure may be fatal.

In cases of acute benzene poisoning the central nervous system is first affected. The severity of poisoning depends mainly on the concentration of benzene vapors in the air and on its time of action. Short inhalation of benzene vapors at low concentrations causes excitation of the central nervous system followed by sleepiness and lethargy, the patient complaining of headache, dizziness, nausea and noises in the ears.

When high concentrations of benzene vapor have been inhaled the effects of excitation are replaced by cramp and loss of consciousness. In severe cases respiratory paralysis can rapidly cause death. /183

Although acute poisoning is not excluded when working with benzene the principal danger is chronic poisoning which can develop over a long time through the respiration of even low concentrations of benzene. Typical of chronic poisoning is disturbance of the central nervous system in the form of increased fatigue, sleepiness and general weakness. Besides this, there is a change in the composition of the blood reduction in the number of its components (red and white corpuscles and platelets), reduction in the quantity of hemoglobin, reduction in blood coagulation. Increased permeability of the blood vessels and reduced coagulation of the blood in benzene poisoning is a cause of bleeding from the nose and gums and also of small hemorrhages on the skin and mucous membranes. Liquid benzene, if it frequently falls on the skin, causes fairly severe irritation, inflammation, itching, swelling and the like.

Prophylactic measures and rules for the provision of first aid in cases of benzene poisoning are mainly the same as for gasoline poisoning.

Dichlorethane

Dichlorethane is a colorless liquid of aromatic smell; its vapors are 3.5 times heavier than air.

In aviation practice, dichlorethane is used mainly as a solvent in carrying out various tasks. The maximum permissible concentration of dichlorethane vapors in the air is considered to be 0.05 mg per liter.

Exposure of the human organism to high concentrations of dichlorethane vapor can cause severe poisoning because of the narcotic and specific effect of dichlorethane on the kidneys, liver and organs of sight. Inhalation of dichlorethane vapors for 2-3 hours at a concentration of 0.3-0.6 mg per liter causes acute poisoning.

The most typical symptoms of dichlorethane poisoning are: headache, sleepiness, sweet taste in the mouth, nausea, vomiting, general weakness, trembling of the extremities, and in more severe cases loss of consciousness and weakening of cardiac activity. In some cases there is irritation of the mucous membranes of the eye and respiratory duct. When dichlorethane enters the organism there occurs most severe poisoning which can be fatal. Systematic action of di- /184
chlorethane on the skin can lead to irritation and even inflammatory effects.

Prophylactic and first aid measures are the same as for gasoline poisoning.

Kerosene

Kerosene is a distillation product of petroleum. In recent years kerosene has become one of the main types of fuel for jet engines. Moreover, it is extensively used on airports and in aviation workshops as a solvent for washing parts, engine components and other purposes.

Kerosene vapors cause greater irritation of the mucous membranes and are more poisonous than gasoline vapors. However, because of the comparatively low volatility of kerosene concentrations in the air, acute poisoning rarely occurs. The maximum permissible concentration of kerosene vapors in the air is considered to be 0.3 mg per liter.

In practice it is necessary to consider the possibility of kerosene poisoning when its vapors are inhaled. Such cases can occur in enclosed ill-ventilated premises where during the process of work with kerosene a large quantity of its vapor may accumulate. Poisoning may be acute or chronic.

Acute poisoning is characterized by excitation, dizziness, headache, then there is loss of consciousness and disturbance of respiration.

In cases of chronic poisoning by small concentrations of vapor, there is disturbance of the central nervous system taking the form of reduced ability to work, disturbed sleep, irritability, etc. There is a parallel development of anemia. Frequent and prolonged exposure to kerosene on the skin is much more dangerous than contact with gasoline. The exposure of the skin to kerosene can cause acute and chronic inflammatory illnesses and also eczema.

Prophylactic measures in dealing with kerosene and first aid on poisoning with it are the same as for gasoline.

Technical Lubricants /185

After prolonged exposure of the skin to lubricating oils the sweat glands become clogged with a development of so-called "oil pimples" which are centers of purulent infection of the skin. The occurrence of purulent infections of the skin is promoted by any kind of cut or scratch.

Statistical data indicate that purulent diseases of the skin are frequently encountered in engine mechanics, the technical staff and workers of aviation repair workshops. These diseases frequently necessitate release from work and cause heavy losses of labor.

Accordingly, prophylactic measures to prevent purulent diseases of the skin acquire considerable importance. All technical staff of sections and workers in workshops should be provided with sufficient quantity of clean soft cloth for wiping the hands which are soiled with oil. Facilities for washing the hands with clean kerosene and hot soap and water should be provided at all work places. Where possible, shower baths should be provided for use at the end of the working day.

CHAPTER XI

MEDICAL SERVICE IN RELATION TO FLIGHTS

A comprehensive medical service relating to flights includes measures for preventing accidents during flights and for preserving the health of the air crew. /186

For this purpose the medical service of Air Force units carries out daily medical observations of the air crew performing high-altitude flights or training to make sure that the personnel comply with the Order of the Day established by the Command and the medical service (duration of working day on flight days and days between flights, time of sleep, diet, etc.). All other necessary therapeutic-prophylactic measures are also carried out in a systematic manner.

The medical services of Air Force units should organize their work in accordance with the combat and training requirements.

The medical service accordingly establishes a working plan which must comprise the following basic measures:

- a routine check of the air crew by the Air Force medical commission must be prepared and carried out;
- the decision of the Air Force medical commission must be put into effect;
- there must be regular periodical medical examinations of the air crew during the periods between the session of the commission and prior to flights;
- high altitude tests and special training of the air crew;
- the special clothing, the oxygen equipment of the aircraft, high altitude compensating suits, as well as anti-g suits must be checked from a medical point of view;
- the quality of the oxygen used must be checked organoleptically; /187
- the air pressure, temperature and moisture in the cabin as well as freedom of the cabin air from obnoxious contaminations must be checked periodically;
- observation of the Order of the Day with regard to working time, rest, and nutrition must be supervised;
- the staff's accommodation and quarters, as well as observation of prophylactic measures in the repair workshops and during work with technical liquids used in aviation, also must be supervised from a medical point of view;
- the presence and intactness of first-aid outfits on board the aircraft must be checked;
- flying and technical personnel must be given lectures on the principles of aviation medicine and military medical training;

- all necessary therapeutic-prophylactic measures must be carried out;
- the physical training of the staff must be supervised from a medical point of view.

Correct aviation-medical expert opinion is of the greatest importance for the prevention of accidents during flights and for ensuring the necessary conditions.

The Air Force doctors have to perform intensive preliminary work long before actually examining the flying personnel: laboratory analysis and X-ray investigations must be carried out. At the last stage of the preliminary work a detailed medical file must be made for each pilot.

A decision concerning the fitness of a pilot for flying is made at the sessions of the Air Force Medical Commission in the presence of the Commanding Officer (or his deputy) and the Air Force unit physician. In case of doubt all the specialists on the commission must make a detailed investigation, after which the opinion of the Commanding Officer and the unit physician concerning the pilot in question must be heard. It is decided then whether the pilot is fit to fly or whether he should be admitted to the hospital for further investigation. After certifying the fitness of the flying personnel, the unit physician has to draw up a plan for implementing the decisions of the Air Force Medical Commission, and this plan must be carried out within the time stated.

Particular attention must be paid to crew members who show signs of ill health between the session of the commission: they must be sent to the hospital if their health deteriorates. Persons with signs of ill health during a routine medical check-up or on sick parades, must be kept under medical observation and must be admitted to the hospital if the case requires a more detailed investigation. On one or two occasions between the sessions of the commission the air crew must undergo a thorough check-up. Specialists and personnel of aviation medicine laboratories and aviation hospitals must take part in these investigations which will then secure a high standard of medical supervision. /188

An important and difficult part of the duties of a medical officer in an Air Force unit consists in the examination of the crew before flights. The following points must be considered before certifying a pilot as fit to fly: his state of health, the nature of his task, compliance with the established regime in the period preceding the flight and with the rules of rest and nutrition.

If the medical officers attached to the unit organize the flight medical service correctly, they will start with the compilation of the Order of the Day for the flight. The plan for the flight medical service must be prepared after the nature of the imminent flight has been discussed precisely with the Commanding Officer and after a list of the pilots who are to take part in the flight has been compiled.

A doctor assesses the fitness of an individual pilot by comparing the results of the daily check-ups with the demands of the imminent exercise and reports his findings to the Commanding Officer.

The medical service must be guided by the following considerations while supervising the regime of work, rest and nutrition observed by the air crew:

1) The duration of the flights (per day or per week) must not exceed the limits established by the Air Force Command for the type of aviation in question.

2) On the eve of the flight the crew must have at least 7-8 hours sleep. The crew must have normal rest before night flights in cases where an exercise lasting over 24 hours is planned.

The following points must be considered when organizing the nutrition of the air crew:

- the crew should have four meals a day, which preferably should be consumed in stationary canteens; /189
- at least 1.5-2.5 hours should elapse between the last meal and the flight;
- it is not advisable to carry out flights on an empty stomach or immediately after a rich meal;
- the rations of the air crew should comprise food of high caloric value, it should be easily digestible, and it should contain adequate quantities of minerals and vitamins - above all, vitamins A, B and C;
- consumption of alcoholic beverages must be categorically prohibited on the eve of a flight and even more so immediately before a flight.

3) Transport of the crew to the airport and back must be organized on the day (night) of the flight and the crew must be free of all other tasks, by reducing the various workday routines to a minimum etc.

Every pilot must be well aware that systematic physical training considerably increases his resilience to harmful factors during the flight and hence will improve his performance and help to preserve his fitness.

Experience has shown that medical observation of the crew will be of the highest standard if the medical officers take part in all preparations for the flight and, above all, in the preliminary training before the flight. During this period, the medical officer is able to discuss with the pilots all questions concerning the influence of flight factors upon the human body, the oxygen supply and the use of anti-g suits, pressure suits and other equipment. These discussions will reveal the standards of training in the field of aviation medicine and the pilot's capacity to make intelligent use of life-saving equipment.

The medical officer should carry out a last check-up in the airport sick-bay and make sure that every member of the crew has had an adequate rest before the flight. The doctor judges the state of health and the fitness of the pilot for the flight by individual conversation and by medical examination in the course of this last check-up.

The air crews should give truthful reports on their fitness, on their compliance with the established regime, and on their readiness to /190 carry out the task in the course of the medical check-up preceding the flight. To secure a better understanding these rules must be explained not only by the medical officer but also by members of the administration unit as well as by Party and Komsomol organizations.

The check-up preceding the flight ends with the doctor's report to the Commanding Officer, which should comprise the doctor's findings concerning the fitness of the individual crew members and with the signing of the flight plan. If pilots are found to be unfit for the flight, the fact must be reported to the Commanding Officer and corresponding amendments made to the flight plan.

After the flight, the crew must be examined again by the unit medical officer. The physician should also, in the course of the medical check-up preceding the flight, pay attention to the health of the technicians servicing the aircraft, as this might help to prevent accidents during flight. Persons may be discovered in the course of this check-up who are unfit to service adequately an aircraft before flight.

The following points must be kept in mind always by the Air Force medical service: continuous checking of the quality of the oxygen, the condition of the oxygen masks, correctness of fittings and switches; familiarity of the crew with the correct use of respirators, scaphanders and anti-g suits.

The Air Force unit doctor takes part in the analysis of the flight after its completion. He should analyze carefully any defects in the organization of the flight which might have led to accidents. He should listen to the assessment of the performance of the crew given by the Commanding Officer and should note any errors committed by individual pilots, comparing them with the medical findings. He should report the results of this comparison to the Commanding Officer.

The physician has to insist on strict compliance with the regime of rest, work and nutrition to prevent over-tiring the members of the crew.

At the first signs of fatigue in pilots, the flight tasks must be /191 reduced, the pilots must be given time off within their quarters for several days. Alternatively, they may be sent for 7-10 days to rest homes, be given special leave or may be sent to nursing homes.

Particular effort should be made to secure normal conditions at the airport and adequate rest for the crew and technicians. For this purpose tents or huts can be built at the airport in the summer, and these must be provided with satisfactory ventilation; ample supplies of cold drinking water must be available and showers should be built. Showers prevent heating of the body in hot weather and serve to wash off sweat and dust from the skin. In winter the medical service should supervise the hygienic standards in the quarters and other buildings at the airport designed to secure rest and warmth for the crew and technicians.

An important task of the medical service within Air Force units consists in the organization of systematic lectures on the basic principles of aviation medicine, sanitary training, protective and first-aid measures against means of mass destruction. These lectures should be held during the time reserved for training and can take the form of short talks with small groups of crew and technicians.

The medical service should systematically check equipment at the airport sick-bay and see that it is ready to provide qualified medical assistance when required or secure the evacuation of casualties into therapeutic institutions.

CHAPTER XII /192

INJURIES TO THE HUMAN BODY CAUSED BY ATOMIC WEAPONS; PROTECTION AND FIRST-AID MEASURES

As is well known, it is necessary to discriminate between two types of atomic weapons: atomic weapons which have an explosive effect and combat radioactive substances.

The Effect of Atomic Explosions on Human Beings

In atomic explosions injuries of various types are caused by the shock wave, the light radiation and penetrating radiation. The magnitude of an atomic explosion and the injuries caused by it is many times that caused by conventional bombs and projectiles.

In addition, a distinguishing feature of an atomic explosion is the presence of light radiation and penetrating radiation. As a result, an atomic explosion has a colossal, destructive effect and leads to very large scale multiple injuries to people who are not under cover. Some of the people affected may experience a specific illness, namely, radiation sickness caused by the effect of penetrating radiation.

People may be injured either at the instant of the atomic explosion, or after it if they enter an area contaminated by radioactive substances.

The nature and the degree of injury during atomic explosions depend on the conditions pertaining at the instant of the explosion (distance from the center of the explosion, degree of protection, etc.). The scale /193 and degree of injury is also influenced by the meteorological conditions during an atomic attack. Cold in winter and very hot weather in summer aggravate the combined effect of physical injury and radiation sickness; the wind, particularly during dry weather, spreads fire, leading to an increase in burn-type injuries. Rain and snow accelerate the precipitation of radioactive dust and increase the radioactive contamination of the clothed and unclothed parts of the body.

As an example of large scale combined injuries during atomic explosions, the data from the Japanese and American literature can be quoted relating to the atomic bombardment of Hiroshima and Nagasaki.

At the time of the attack Hiroshima had 300,000 and Nagasaki 200,000 inhabitants. Of these 500,000 inhabitants, 215,000 were injured, about 110,000 fatally. Consequently, out of a population of 500,000, 43% suffered injuries and 22 % perished.

According to data of various authors relating to Hiroshima and Nagasaki, almost 100% of the people who were inside a radius of up to 0.5 km from the epicenter of the explosion died; in the zone 0.5 to 1 km from the epicenter the percentage of deaths was still very high (80-90%); in the zone within a radius of 1-2 km, the death rate was considerably lower, while beyond 2.5 km from the epicenter of the explosion only 0.5% perished.

Approximate calculations have shown that the shock wave was responsible for 50-60% of the deaths, 30-40% were due to light rays and fire and the remaining 5-15% were caused by radioactive radiation. Undoubtedly, the fact that there was such a large number of victims in Hiroshima and Nagasaki was due to the unpreparedness, the suddenness of the atomic attack and the panic of the population.

Calculations have shown that 70% of the victims suffered physical injuries, 75% suffered burns, 30% radiation injuries; this totals 175% and indicates that most of the victims suffered combined injuries.

For clearer elucidation of the injuries to the human body caused by an atomic explosion, it is advisable to study separately injuries caused by the shock wave, the light radiation, the penetrating radiation and the radioactive substances and then to characterize the features of combined injuries. /194

Injuries Caused by the Shock Wave

From the point of view of the injuries caused, the shock wave is the most important. The physical injuries to unprotected people caused by the shock wave of an atomic explosion do not differ from injuries caused by conventional bombs and projectiles. However, the area devastated is much greater.

The injuries caused by the shock wave can be direct or indirect.

The direct effect of the shock wave consists in the short duration impact of the compressed air, which is similar to the impact of a solid body except that the impact is along the entire surface on which the propagating shock wave impinges. The nature of the indirect effect of the shock wave on the human body depends on the magnitude of the pressure in the impact wave, its duration, the position of the body relative to the propagating wave and the properties of the individual organs and tissues.

The impact of the wave on the surface of the human body generates a compression wave which propagates into the tissues and organs at a high velocity (about 1,500 m/sec). If the magnitude of the pressure of the wave exceeds a certain limit which a given type of tissue can withstand, the continuity of the tissue will be disrupted. Organs containing large quantities of gases (lungs, intestines) as well as organs containing large quantities of blood (liver, spleen) and organs with liquid filled cavities (brain chambers, gall bladder) suffer the most severe injuries.

Compression and subsequent expansion of air in these organs are accompanied by multiple tissue injuries, particularly on the side facing the shock wave.

Under the effect of compression, there will be a powerful hydraulic impact on organs which contain large quantities of fluid and this impact may disrupt the blood vessels, the gall bladder, the urinary bladder, the liver, spleen and other organs. /195

Traumas caused by the direct effect of the shock wave of an atomic explosion may vary greatly; they may vary from mild bruises to the severest possible injuries which may cause immediate death to an unprotected person.

An excess pressure of the shock wave of 0.4-0.6 kg/cm^2 will affect the acoustic organs and cause contusion (shock), and a pressure exceeding 1 kg/cm^2 is usually fatal to both humans and animals.

A person not under cover can be thrown a distance of several dozen meters by the shock wave. In such a case the injury will be even more severe by the fall of the body, additional contusions and concussions in various organs, primarily of the brain (contusion and concussion of the brain), as well as by other traumas.

It is pointed out that the clinical picture of the injuries to a human being caused by a shock wave is a very complex one. In most cases, multiple functional disorders of the central nervous system predominate. These are characterized by a general stupor, tension of the muscles, disorders in gait, slow movements, sleepiness and sometimes psychic disorders. In addition, there is a fall in blood pressure, an acceleration (tachycardia) and then a deceleration (bradycardia) of the pulse and an increase in the frequency of respiration, etc. Severe injuries may result in death.

Experimental investigations carried out in recent years on animals have shown that basically fatal injuries caused by the shock wave are due to destruction of the lung tissue (rupture of the alveoles, small bronchi and small blood vessels), which occur most frequently as a result of the impact of the explosion shock wave on the surface of the chest. Observations on human beings have shown similar results, here as well the trauma of the lungs is of focal importance. In such cases, rupture of the tympanic membrane, injuries to the stomach, intestine, liver, spleen, kidneys and other organs may occur in addition to injuries to the lung tissue.

The destructive effect of the shock wave in water is far higher than the effect of a shock wave in air. In water, the internal organs of a person swimming at a distance of 65-70 m from the point of explosion of a 200 kg bomb may be injured. Obviously, in the case of an atomic /196
explosion, the perimeter in which injuries may occur will be considerably

larger. Particularly, the parts of the body submerged in water and those organs containing air (lungs, stomach, intestine) will suffer injury. However, the liver, spleen and kidneys may also suffer injury.

Thus, the direct effect of the shock wave may bring about injuries in the human body differing in localization and severity. However, experience gained during the Second World War, and particularly the atomic bombardment of the Japanese towns of Hiroshima and Nagasaki, have shown that in inhabited places the indirect or secondary injury caused by the debris of buildings and various structures resulting from the shock wave, as well as particles of soil, splinters of glass and other objects carried away by the shock wave will predominate.

In Hiroshima and Nagasaki, people were wounded by flying objects; they were crushed and buried under debris and thrown against walls of structures. Splinters of glass penetrated to a depth of 2.5 cm under the skin. It is pointed out that injury by broken glass occurred at distances up to 10-12 km from the point of explosion. In some cases, injury by glass splinters was observed at a distance of 50 km. Indirect injury may differ in character - from very insignificant scratches right up to fatal injuries, dangerous bone fractures and severe lacerations with intensive hemorrhages.

Among the victims suffering lacerated wounds, there were persons staying at a distance of 3,200 m from the epicenter in Hiroshima and up to 3,700 m in Nagasaki. In many cases, shock (a severe general condition), of emotional as well as of traumatic origin, was a serious complication of the injury.

The indirect injuries caused by the shock wave of an atomic explosion are basically similar to injuries caused by the explosion of conventional bombs, the only important difference being that in the case of an atomic explosion a larger number and a greater variety of injuries develop within a very short time. At an equal distance from the center of the explosion, the shock wave will cause more severe injuries to a man standing upright than to a man lying on the ground. /197
Even the simplest type of cover (ditches, trenches, communication trenches, craters etc.) provide a certain protection against the effects of a shock wave. For instance, the radius of the zone in which dangerous injuries may be caused by a shock wave will be approximately 1.5-2 times smaller for persons taking cover in trenches than for completely unprotected persons. Special shelters secure an even better protection.

Injuries Caused by Light Radiation

The light radiation of an atomic explosion may cause burns in the uncovered parts of the body of unprotected persons and produce damage of a varying degree to the eyes. The burns and eye injuries are due to the direct effect of infrared, visible and ultraviolet rays as well as to the flames of burning clothing and fires; fires may be ignited by the light rays or may be sparked off by electricity supply systems damaged by the shock wave, furnaces, boilers etc.

In towns with a large number of timber buildings, the number of people thus injured may be very high. In Air Force units severe burns resulting from explosions and ignition of gasoline, kerosene and combustible mixtures, etc., may occur in addition to burns caused by the direct effect of the light radiation emitted by the atomic explosion.

Burns caused by light radiation of an atomic explosion are very similar to burns caused by flames, boiling water, etc.

According to the generally accepted classification, there are four degrees of burns which may occur as a result of an atomic explosion.

Burns of the first degree are characterized by hyperemia, slight swelling and tenderness of the skin; they develop after exposure to a light pulse of 2-5 cal/cm^2.

Burns of the second degree are characterized by hyperemia of the skin and the formation of blisters; such burns can arise after exposure to a light pulse of 5-10 cal/cm^2.

Burns of the third degree are characterized by necrosis of parts of the skin and formation of ulcers; such lesions can be observed after exposure to light pulses exceeding 10 cal/cm^2.

In addition, charring of tissues (burns of thefourth degree) may /198
occur after exposure to light pulses exceeding 15-20 cal/cm^2.

The extent of the zones in which burns of various degrees on unprotected persons can be expected can be established approximately from the above given data, as well as from the intensity of the light pulse at various distances from the point of explosion.

In addition to the above mentioned local phenomena, these burns also have certain general clinical characteristics.

The light radiation generated by an atomic explosion may cause burns of uncovered parts of the body of unprotected persons which may vary from mild to extremely severe charring of the tissues, whereby the degree will depend on the distance from the point of explosion and the caliber of the bomb. As a rule, burns of this type can be observed on those parts of the body which are facing an explosion and are exposed to a direct beam of light. Therefore, any object shielding a person from a direct beam of light (wall, fence, natural depression in the terrain, clothing) will protect a body from injury by light radiation. However, burns can develop not only on the uncovered part of the body but also under the clothing if the clothing fits tightly to the body. Such burns are referred to as "contact burns", since they develop as a result of the contact of the intensively overheated clothing to the skin.

It is obvious that the degree of injury caused by light radiation on covered parts of the body surface will depend primarily on the protective properties of the clothing. The type and color of the material, its density, thickness, number of layers and the tightness of fit will affect appreciably the extent and degree of the burns. Loose, light-colored clothing will give a much better protection than dark, tight-fitting clothing. Clothing made of wool or linen is the most resistant to the effects of light radiation.

In Hiroshima and Nagasaki there were cases in which the same person suffered burns on his skin under the dark-colored parts of his clothing although the skin underneath light-colored clothing suffered no injury at all. In other words, patterned burns developed. Burns caused by light radiation in Hiroshima and Nagasaki varied greatly in degree and intensity. In some cases, even charring of the skin was observed.

In persons exposed to the action of luminous radiation, reddening /199
of the exposed parts of the skin could be observed immediately after the explosion. After a few hours, the reddening was replaced by progressively increasing dark pigmentation and formation of blisters. The further course of the burns depended on their degree and was in no way different from the course of common burns caused by flames.

In addition to the so-called flash burns caused by light rays, a great number of burns in the case of atomic explosions are caused by the flames of fires.

It may be of interest to point out that in the atomic explosions in Hiroshima and Nagasaki, up to 75% of all victims suffered burns of various degree, either due to light rays or to fires, whereby the number of fatal burns reached 50% of the total number of fatal cases. Up to 1,000 m from the epicenter of the explosion, burns can also be caused by hot air.

Due to the vast scale of the injuries caused by burns, it is absolutely necessary to apply extensive protective measures and prepare an adequate first aid organization for helping victims of burns in the case of similar catastrophes.

Eye injuries. The light rays emitted by the atomic explosion may cause eye injuries of different degree. The cause of these injuries lies in the direct effect of ultraviolet, visible and infrared rays. The degree of the injury will depend on the intensity and the spectral composition of the radiation.

Ultraviolet rays cause conjuctivitis, and in more severe cases inflammation of the cornea. Lesions of this type appear approximately within 8-12 hours and are characterized by severe pain, photophobia and lacrimation.

The infrared rays may cause burns on the eyelids, the conjuctiva and the cornea, and may also lead to opacity of the crystalline lens, which may develop after some time, several months or even years. When acting upon the retina, the visible part of the spectrum causes temporary blindness. As an example of the blinding effect of the light rays emitted by atomic explosions, published Japanese and American data are quoted, concerning the results of the atomic bombardment of Hiroshima and Nagasaki, which was carried out during the day in bright sunlight. Temporary blindness frequently occurred in persons who directly observed /200 the flash of the atomic explosion with unprotected eyes, even from a distance of 10-12 km. This blindness lasted in most cases from several minutes to half an hour, and only in a single case lasted for two days.

What is the mechanism leading to this sort of blindness?

According to modern conceptions, the temporary blindness caused by exposure of the eyes to strong light may be caused by the following:

Firstly, strong light leads to complete exhaustion of the visual purple in the photosensitive cells (rods and cones) of the retina. In this case, the blindness will last for as long a time as is required for the restoration of the visual purple to a degree sufficient for normal vision. This process requires, as a rule, from several minutes to half an hour.

Secondly, temporary blindness may be caused by the fact that the crystalline lens concentrates the light rays and the particular infrared rays in a focus on the retina. The so-called "shielding blindness" which occurs in those cases when a person looks into the sun may serve as an example of blindness of that kind. Both factors mentioned above may complement each other, causing a more marked blinding effect. Besides, numerous specialists in opthalmology have, on the basis of experimental data, recently voiced the opinion that in these cases the optic center (which is located in the cerebral cortex) takes part in the mechanism leading to temporary blindness. The powerful beam of light to which the retina is exposed for a moment, leads to the breakdown of a great number of visual purple molecules and in consequence an enormous number of electrical pulses will be generated in the photosensitive cells, which enter "like an avalanche" the nerve cells of the optic center, thus inducing an inhibitory process which paralyzes their activity for some time.

Temporary loss of vision may arise even after exposure to pulses not exceeding 0.3-0.5 cal/cm^2. During explosion of a medium caliber atomic bomb, pulses of this order can be observed over a distance of 10-12 km.

Since light rays emitted during an atomic explosion include ultraviolet, visible and infrared rays, the eye injuries may be of complex /201 character. However, these injuries can be observed only if the light impulses are of adequate strength, equal to about 5-10 cal/cm^2.

The assumption has been voiced that the excessively bright light flash occurring at the moment of explosion causes a momentary protective reflex: closing of the eyelids which, in consequence, protects the eyes against injury. Recently, however, serious arguments have been raised against the assumption concerning the protective role of the blinking reflex. Various authors emphasize that 35-50% of the light energy released by the flash of an atomic explosion reaches the human eye within the first 0.001 seconds, i.e., much earlier than the blinking reflex which requires an average of 0.1 seconds. In other words, a quantity of light energy sufficient to cause injuries reaches the eyes before the lids can be closed.

Under combat conditions, air crews may be exposed to powerful light flashes caused by atomic explosions both during the day and at night.

At present, the necessary conditions have been created to permit firing of atomic shells by one aircraft at another. Also, use of atomic shells against aircraft by ground-based anti-aircraft artillery is very likely. Atomic shells may explode in front, at the side, above the aircraft, etc., at various distances from it. In all these cases there will be an instantaneous increase in light intensity. The light rays emitted by the atomic explosion may exert an unfavorable effect upon the pilot even if, due to distance, injuries caused by the shock wave and penetrating radiation do not occur.

Let us imagine that, at a distance of 5 km in front of an aircraft, an atomic shell with a trotyl equivalent of 2000 t explodes in front of the pilot's eyes in daytime, in bright weather, when the natural illumination intensity reaches 100,000 lux. For a moment, the illumination intensity in the neighborhood of the aircraft increases to 5 million lux, i.e., to 50-100 times the natural intensity. This powerful instantaneous increase in the intensity of illumination, to which the eye is not at all accustomed, may lead to temporary blindness and incapacitate the pilot even in daytime.

If under similar conditions such an atomic explosion were to take place at night when the natural illumination intensity is 0.01 lux, the light intensity of the atomic explosion will produce an instantaneous increase in brightness by 500 million times. If the increase in strength /202
of a light pulse with altitude is taken into account, the increase in brightness will be even greater, which will undoubtedly blind the pilot and will paralyze his fighting capacity for some time.

In view of what has been said above, it is essential to protect the flying personnel against injuries caused by the light rays of atomic explosions, particularly protection against the blinding effect which might paralyze the combat capability of the crew at a critical moment during the performance of their task. At present it is hard to say along which lines the solution of this problem will lie.

A tentative opinion is that the most rational protection of the aircrew against the blinding effect of light rays emitted by an atomic explosion may be secured by means of special equipment ensuring a full blackout of the aircraft cabin during certain periods of the flight. In this case piloting the aircraft, as well as all actions concerned with the combat mission will have to be carried out exclusively by instruments. Such a measure will undoubtedly render the flight and fulfillment of the combat assignment more difficult. However, such measures may be fully justified if the combat assignment is accomplished successfully, in the case that the enemy employs atomic missiles.

Injuries Caused by Highly Penetrating Radiation

Injuries caused by highly penetrating radiation are a characteristic feature of the effect of atomic weapons on the human body. As a factor causing injuries, highly penetrating radiation represents a qualitatively new phenomenon characteristic only of atomic weapons. Injuries caused by penetrating radiation have nothing in common with those caused by the shock wave, the light rays of the atomic explosion or with injuries caused by other types of weapon. During exposure to such radiation, man does not feel pain or any other unpleasant sensation. However, after some time has elapsed, a specific illness, radiation sickness, develops in a person who has been exposed to the action of penetrating radiation.

Until recently, similar cases occurred in radiologists, as well /203
as in persons who had been working for a prolonged period with radioactive substances.

The injurious effect of high penetrating radiation is due to its capacity to penetrate tissues and organs of the living organism to varying depths, producing in these ionization of molecules. Ionizing radiations include alpha-particles, beta-particles, neutrons, X-rays and gamma-rays.

The primary mechanisms responsible for the biological effect of different ionizing agents are very similar. What then is this common primary mechanism which is responsible for injuries caused in the living organism by various types of penetrating radiation?

As follows from the name itself, whatever the type "penetrating or ionizing" radiation can expel electrons from atoms or molecules in the substance exposed to radiation, thus causing ionization in these.

In the most general diagrammatical form, the process can be illustrated as follows:

$$A \sim \longrightarrow e + A^{+},$$

$$e + B \longrightarrow B^{-}.$$

In other words, the molecule, A, loses an electron and becomes a positively charged ion (A^{+}); and the expelled electron which joins the molecule, B, turns this into the negatively charged ion (B^{-}).

Penetrating radiation, gamma rays, beta and alpha-particles may cause ionization of molecules not only in a number of complex organic and inorganic compounds, but also of water molecules. This is of great importance as the vital processes take place in an aqueous medium and the water content in various organs and tissues reaches up to 85% of their mass. Ionized molecules easily enter new bonds and form new substances. Thus, for example, in the aqueous medium of the animal body, hydrogen peroxide and other oxidizers will form which are highly toxic to the tissues; these substances lead to the formation of other toxic substances. In this manner toxic substances accumulate in the body and start off a complex chain of phenomena associated primarily with metabolic disorders. All these cause intoxication of the body and impairment of the vital functions, which can lead to the death of individual cells and even tissues. In their turn, the products of decomposition of the cells have a damaging effect upon the body. /204

The disorders mentioned above primarily affect the functioning of the central nervous system which controls and monitors the activity of all organs and of the body as a whole. In other words, exposure of the human body to highly penetrating radiation leads to radiation sickness of greater or lesser severity.

In the case of an atomic explosion, it is mainly the gamma rays and neutrons which have a damaging effect upon the human body. Compared with other types of radiation, the ionizing capacity of the gamma rays is relatively small. However, since the gamma rays are highly penetrating, they may cause severe injuries in vitally important organs and in the body as a whole. Injuries occur both during the actual atomic explosion and afterwards, if people remain in places contaminated with radioactive products.

The neutrons, which are highly penetrating as well as highly ionizing, can penetrate easily into the human body and cause injuries.

However, compared with injuries caused by gamma rays, those caused by neutrons spread over a smaller area. Moreover, at equal distance from the point of explosion, the dose of the neutrons reaches only about 30% of the dose of gamma rays. In certain cases, however, the effect of the neutrons will predominate. The injuries caused by neutrons occur only at the instant of the atomic explosion.

A characteristic feature of injuries suffered by humans and animals due to neutrons is that artificial radioactive isotopes form in the tissues and organs; these isotopes intensify the injurious effect of the neutrons themselves.

Overall irradiation causes injuries to the whole body, while irradiation of individual parts of the body leads to local injuries which are frequently accompanied by a general reaction. For instance, in treating malignant tumors one frequently uses local exposure to X-rays, rays emitted by radium, and radioactive cobalt in very high doses without any serious consequences. However, exposure of the head or abdomen to large doses may lead to severe disorders of the whole body. The individual sensitivity to radiation and the condition of the body at the time of exposure exert a crucial influence upon the result of exposure to penetrating radiation. In different people the same dose of radiation may cause radiation sickness of varying severity. Anything which weakens the body, for instance, various diseases suffered shortly before exposure, excessive physical fatigue, burns, injuries and other lesions accompanying the radiation, will increase the sensitivity of the body to highly penetrating radiation. However, the basic factor which determines the degree of the injuries caused by penetrating radiation is the radiation dose to which the body is subjected. /205

The dose is defined as the total quantity of radiation absorbed by the body throughout the period of exposure to radiation. Consequently, it has been established that:

- if the whole body is exposed to penetrating radiation in doses under 50 roentgen, usually no illness whatsoever develops and, consequently, a single exposure of the human body to a dose of this order is regarded as permissible;

- exposure to radiation in doses between 100 and 200 roentgen causes radiation sickness of the first degree, in the course of which the first mild symptoms of the disease appear; the victims rapidly recover and no fatal cases have been observed;

- exposure to radiation in doses between 200 and 300 roentgen may cause radiation sickness of the second degree and, in the majority of cases, the patient will recover;

- exposure to radiation in doses between 300 and 500 roentgen may lead to development of radiation sickness of the third degree; provided effective methods of treatment are used, this may not be fatal.

To all that has been said above, it is necessary to add that the severity of the illness depends not only on the total dose but also on the period over which the dose was received by the patient. For instance, a dose of 200 r received by a person in the course of a single day may cause radiation sickness of medium severity. The same dose received in small portions over the course of a year will not as a rule lead to the development of radiation sickness. At the same time, one has to allow for the phenomenon of accumulation of radiation doses received by a person at short intervals.

The Injurious Effect of Radioactive Substances /206

Radioactive substances include products which are formed during atomic explosions as well as specially prepared radioactive combat substances.

The products of an atomic explosion represent inevitably sources of contamination of an area surrounding the explosion and along the path followed by the radioactive cloud.

Radioactive substances can act upon the body by external irradiation and also by entering the body - by irradiation from the inside. The nature of the radiation injuries will depend not only on the method of irradiation (external or internal) but also on the type of radiation.

The products of an atomic explosion emit gamma rays, beta- and alpha-particles. The effect of gamma rays emitted during the radioactive disintegration of explosion products is in no way different from the effect of gamma rays emitted at the moment of the actual atomic explosion. If people remain in areas contaminated by the radioactive products of an atomic explosion (provided entrance of these products into the body as well as onto the skin or mucous membranes of the body is excluded) the lesions will be caused mainly by the gamma rays, which have a great penetrating capacity. The beta-particles have a much lower penetrating capacity and enter the body in the case of external exposure only to a depth not exceeding 3-5 mm.

A summer uniform will block up to 30-40% of the beta-particles. For this reason the injurious effect of beta-particles in the case of external exposure is relatively small. However, the intensive flow of beta-particles may cause serious eye injuries. In consequence, one should always bear in mind the protection of the eyes. The degree of eye injury can be diminished to a considerable extent by ordinary eye-glasses or eye-pieces in gas-masks.

If radioactive products of an atomic explosion enter the body, the injurious effect is mainly caused by the beta-particles. This can be explained by the fact that the beta-particles have a higher ionizing capacity than the gamma rays. In addition, the number of beta-particles emitted by the fission products is about two or three times higher than the number of the gamma quanta emitted.

As far as the alpha-particles are concerned, they have the lowest penetrating capacity and the highest ionizing capacity of all types of radiation. In the case of external exposure, alpha-particles are completely kept back by the external layers of the skin. Injuries caused by alpha-particles can, as a rule, arise only on direct contact with alpha-active substances. /207

If the skin, as well as the mucuous membranes of the mouth, nose and eyes, comes into contact for a prolonged period with radioactive substances, local lesions in the shape of superficial burns and ulcers may develop.

Radioactive substances are most harmful in those cases where they enter the body. Radioactive substances can enter the body through the respiratory tract (through contaminated air), through the gastro-intestinal tract (with contaminated food products and water), through the mucous membranes, as well as through the surface of wounds and burns, and are then absorbed into the blood; the blood stream then carries the substances all over the body.

The greater part of the radioactive substances which enter the body is excreted within 2-3 days with the urine and the stool. The remainder of the radioactive substances can stay for a prolonged period in the organs and tissues, causing lasting injuries in the body by way of radiation. The bones, the liver, the kidneys and spleen are those parts of the body in which the greatest quantities of radioactive substances are deposited. The most severe injury can be observed in those organs through which the radioactive substances enter the body, as well as in those organs and tissues in which the radioactive substances are deposited.

If radioactive substances are inhaled with contaminated air, they will affect above all the upper respiratory tract and the lungs, and if they are consumed with contaminated food and water they will mainly affect the gastro-intestinal tract. The degree of damage will mainly depend on the dose of radioactive substances which has entered the body. The degree of injury, however, will also depend on the chemical nature of the radioactive element, the type of radiation, the half-lifetime, the rate of excretion from the body, and other factors. If large quantities of radioactive substances enter the body, radiation of different degree may develop in addition to the local injuries.

Radiation Sickness /208

In medical practice we discern two forms of radiation sickness: acute and chronic. The acute form of radiation sickness usually develops due to a single or repeated (within a short interval) exposure to a high dose of penetrating radiation. The chronic form of radiation sickness develops after prolonged repeated exposure to small doses of radiation.

Under combat conditions, we may encounter both acute and chronic radiation sickness.

A single exposure to high doses (e.g. in the case of an atomic explosion) as well as repeated exposure to high doses within a relatively short period (e.g. when work is carried out in areas with a high degree of contamination) will lead to the development of the acute form of radiation sickness.

Repeated prolonged exposure to small doses (e.g. working with objects contaminated by radioactive substances or in places where the level of radiation is low) will lead to the chronic form of radiation sickness.

Radiation sickness, like any other disease, has its own characteristic symptoms and typical course.

Depending on the degree of the illness, these symptoms may appear at different periods after exposure, and the degree of their manifestation may vary considerably.

We discern the following stages in the course of radiation sickness:

a) the initial period, characterized by the primary reaction of the body in the shape of general malaise, headaches, vertigo and sometimes nausea; frequently, however, no primary reaction develops;

b) the latency period, which follows after the primary reaction, in the course of which the person may on the surface seem perfectly healthy; the duration of the latency period will depend on the dose of radiation (the higher the dose, the shorter the latency period); and it may last between several hours and 2-3 weeks; in severe cases the latency period may be absent and primary reaction may be followed immediately by a typical picture of radiation sickness;

c) the peak period of the illness;

d) the period of recovery.

What then are the causes of radiation sickness? In cases of radiation sickness the patients most frequently complain of general weakness, loss of appetite, depression, sleepiness, headache, vertigo, abdominal pains and frequent bowel motions. /209

The complaints enumerated above can be evaluated in the absence of concomitant injuries or diseases as early manifestations of radiation sickness.

The most typical symptoms of radiation sickness include:

1. Generally lowered activity of the patient (weakness, decreased mobility, apathy, loss of appetite, sometimes complete anorexia).

2. Gastro-intestinal disorders (nausea, vomiting, diarrhea).

3. Tendency to bleeding in the form of isolated or multiple hemorrhages on the skin and the mucous membranes. Hemorrhages on the skin appear particularly frequently in the upper half of the body (head, face, chest, forearms). The size of individual hemorrhages can be different: between punctiform hemorrhages to large ones up to 1 cm and more in diameter.

4. Loss of hair, a symptom which can usually be observed beginning from the second week after exposure. It is characteristic that the hair easily falls out at the slightest touch. Taking into account the fact that the symptoms of radiation sickness enumerated above develop slowly and are not simultaneous, medical institutions have to carry out laboratory investigation as early as possible after exposure. Analysis of the peripheral blood (taken from the finger) represents the most objective method of early diagnosis of radiation injuries. In the first hours after exposure to radiation, the number of white cells (leucocytes) in the peripheral blood increases for a short time as a rule; this increase is followed regularly by a gradual decrease. At the peak of the illness a slow decrease in the number of red cells

(erythrocytes) can be observed. The fall in the number of red cells and the decrease in the percentage of hemoglobin characterize to a certain degree the severity of the radiation sickness and the rate of its development. The more severe the illness, the more rapid the fall in the hemoglobin content.

On the basis of the severity of the illness, radiation sickness is usually divided into three degrees: first degree (mild); second degree (medium severity); and third degree (severe).

Radiation Sickness of the Third Degree /210

In radiation sickness of the third degree all the typical symptoms of this illness develop relatively rapidly. In these cases there is sometimes no latency period at all, or it lasts a total of several hours. Immediately after exposure to radiation the primary reaction usually develops in the shape of weakness, headache, vertigo, nausea and vomiting. Sometimes these symptoms may be absent or, having arisen, they quickly subside in the first hours after the exposure, and somewhat later (after a time varying between several hours and 1-2 days) they recur in a more persistent form. By this time the first symptoms indicating the onset of the peak period of the illness appear: a state of depression, weakness, lack of mobility, loss of appetite or disgust at the thought of food, thirst, and frequent bowel motions.

Later, 4-7 days after exposure to radiation, all the typical symptoms of radiation sickness of the third degree are fully developed: lack of mobility, full anorexia, exhausting diarrhea, multiple punctiform or larger hemorrhages on the skin and the mucous membranes, progressive loss of weight, loss of hair, progressive decrease in the number of white and red cells, raised body temperature, as well as disorders in the nervous system and the cardio-vascular apparatus. Owing to the general weakening of the body, and in particular owing to the decrease in the number of white cells in the blood, resistance to various infections decreases. For this reason, one infection or another may easily develop as a complication, a fact which leads to a further deterioration in the patient's condition. In these cases, radiation sickness is most frequently complicated by pneumonia.

After progressively increasing symptoms and complications, radiation sickness of the third degree may end in death in the second-third week with respiratory and circulatory failure.

If appropriate therapeutic measures are taken in time, the fatal outcome may be avoided.

Radiation Sickness of the Second Degree

Unlike radiation sickness of the third degree, that of the second degree is above all characterized by a slower rate of development.

A primary reaction cannot always be observed in cases of radiation sickness of the second degree, and the latency period may last 7-10 days or even more. /211

During the latency period the patient may give an external impression of being completely healthy, and only in rare cases feel some weakness and increased proneness to fatigue. During this period functional changes in the condition of the body may be detected by means of special methods of medical investigation. It is particularly in this period of apparent well-being that the number of white cells circulating in the blood decreases slowly but at an increasing pace.

It is a characteristic feature of radiation sickness of the second degree that even at the peak of the illness not all the typical symptoms of the illness can be observed.

In these cases the state of depression is less marked, the appetite is not completely lost, and the tendency to bleed is less pronounced.

The changes in the blood picture are also less marked: the fall in the number of white cells is not of a drastic nature, and there is not always a decrease in the number of red cells.

In radiation sickness of the second degree, usually no inflammatory processes or necrosis of the oral mucosa can be observed.

Pulmonary complications (pneumonia) occur only rarely, and as a rule there is no temperature rise.

Provided no complications occur, the illness always ends in the patient recovering.

The period of recovery begins in the 4th-5th week and lasts up to 2-3 months. The basic signs indicating the beginning of the recovery period are: improvement in appetite, decrease of the tendency to bleed, restoration of the normal functions of the gastro-intestinal tract, and mainly, normalization of the blood-forming function of the bone marrow and gain in body weight.

Fatalities are very rare in radiation sickness of the second degree and are mainly due to the development of infections, particularly pneumonia.

Throughout the course of the illness, the danger of complications through infections cannot be excluded. For this reason the patient requires particularly careful nursing.

Persons recovering from radiation sickness of the second degree can, after adequate rest, become fully fit again for work and combat.

Radiation Sickness of the First Degree /212

Radiation sickness of the first degree is characterized by mild symptoms and complete absence of some of the symptoms. The illness is characterized by increased proneness to fatigue, short-lasting vertigo, mild nausea, periodic increases in the body temperature. In the course of the first-second week, certain changes in the blood picture can be observed.

Radiation sickness of the first degree always ends in the patient recovering.

Combined Injuries

We have investigated separately the effect upon the human body of the shock wave, the light radiation and penetrating radiation emitted at the moment of explosion of an atomic bomb, as well as the effect of radioactive substances. In actual fact, however, humans may be exposed to the simultaneous action of several factors in the case of atomic explosions, and this may lead to combined injuries, i.e., simultaneous combination of various forms of traumas with burns, and in some of the victims, traumas, burns and radiation sickness.

Traumas and burns developing in the case of atomic explosions which are not accompanied by radiation sickness are, in regard to their character and course, in no way different from injuries and burns caused by other factors. Combination of traumas and burns with radiation sickness of the second or third degree delays healing of the wounds, bone fractures and burns.

The presence of burns, wounds, bone fractures and other traumas, on the other hand, renders the course of the radiation sickness more severe. Injuries caused by an atomic explosion may be complicated by the action of radioactive substances. They may lead to an increase in the dose of radiation received, to skin infections, wounds, burns on parts of the skin, and to injuries caused when ingested by mouth.

Measures of Protection

Although the atomic weapon represents an extremely powerful force, there are reliable measures of protection even against this weapon.

The main measures consist in the use of various types of constructions and natural cover which:

- decrease (or exclude completely) the probability of being hit by the shock wave; /213

- fully exclude the possibility of being affected by the light radiation;

- decrease considerably the effect of penetrating radiation or completely prevent injury caused by it.

In contaminated areas one has to take measures to prevent entry of radioactive substances into the body or onto uncovered parts of the body surface; these measures include:

- neither to drink, eat nor smoke and to avoid unnecessary sitting or lying on the ground;

- after the signal "chemical alarm" to put on a gas-mask, protective slippers and overcoats.

If the gas-mask is unserviceable, one has to protect the respiratory tract against the entrance of radioactive substances. For this purpose a piece of gauze or handkerchief, folded into several layers and moistened with water can be used as a filter for breathing. Combat conditions permitting, the contaminated zone should be abandoned as quickly as possible.

Rendering of First Aid

During an atomic bombardment of inhabited planes or of troop concentrations in open areas, the number of victims may become colossal within a matter of seconds. In these cases one cannot expect prompt first-aid by medical staff. For this reason, self-help and mutual aid will play an essential part in the general system of therapeutic measures. Self-help and mutual aid will obviously not fully replace the assistance rendered by qualified medical personnel. Consequently, after first-aid has been rendered, it is necessary to ensure that the victim receives a check-up by a doctor or medical assistant as soon as possible.

As has been said above, the victims of an atomic explosion may suffer various types of wounds and injuries, burns as well as radiation injuries. Therefore, when rendering first-aid, it is essential to stop the bleeding, as serious loss of blood is dangerous to life. Each injury, however, harbors yet another danger which should not be forgotten. Even relatively small superficial wounds may become contaminated and infected by micro-organisms which cause suppuration, or the wound may become contaminated by radioactive substances. Wounds /214 of this kind will subsequently fail to heal for a long time, may leave deforming scars or even cause disablement. Micro-organisms and radioactive substances which enter the wound may penetrate into the blood and cause complications in the condition of the victim.

For this reason the following rule must be strictly observed: the wounds must not be touched by hand, must not be powdered, and must not be covered by any leaves or paper. They must not be washed with water, and no splinters or other foreign bodies must be removed from the wounds. The wounds must immediately be covered with a sterile dressing, using for this purpose a dressing package, a bandage or clean material, or cotton-wool tissue. If the hemorrhage is severe, bleeding must be stopped immediately by applying a ligature with any material at hand. If burns are present, sterile dressings must be used to cover them. The main task of first-aid in the case of burns consists not only in the relief of pain, but also in the prevention of infection and protection of the burned area of the skin against micro-organisms which cause suppuration, as well as its protection against radioactive substances.

Victims of an atomic explosion will frequently suffer bone fractures. In these cases the fractured parts must be put in splints, after the wound has been covered, by any means at hand (pieces of boards, sticks, etc.), provided the latter are not contaminated by radioactive substances. While rendering first-aid, wounds, burns and bone injuries must be treated with great caution, sparing the victim any further traumas or painful stimuli which would later have an adverse effect on his recovery. This is particularly important in those cases in which traumas and burns are combined with radiation injuries.

After first-aid has been rendered, the victims must be allowed to rest, and in cold weather they must be protected against chill; in hot weather against overheating. If they have remained in a contaminated zone, immediate measures must be taken to evacuate them from that zone. In all cases it must be borne in mind that early evacuation of victims into therapeutic institutions will help to prevent complications and speed recovery.

The series of measures constituting first-aid also include the decontamination of all persons who have been in the zone of atomic explosions or in areas contaminated with radioactive substances. /215

The decontamination consists in removal of radioactive substances from the skin by washing with water, and from the oral cavities by rinsing the mouth. The decontamination may be partial or complete.

Decontamination

As has been said above, the air, ground, persons who are not under cover and unprotected military equipment and weapons may prove to be contaminated with radioactive substances after an atomic explosion or attack by radioactive combat substances. Persons in contaminated areas are exposed to radioactive radiation. Radioactive substances can, together with dust or earth, infiltrate into clothes, the skin, the conjunctiva, the mucous membranes of the nose, and the oral cavities. In addition, radioactive substances may enter the body with air, food or water.

Radioactive substances deposited on the skin and the conjuctiva, the mucous membranes of the nose or the oral cavities, cause ulcers and inflammation. If the radiation is prolonged or persons are exposed to high doses for short periods, or if radioactive substances enter the body, the victim may suffer from radiation sickness.

In the course of time, radioactive substances decay. Consequently, the degree of contamination of an area and of the objects present in that area will spontaneously decrease. After a time, the radioactive contamination subsides completely. However, the process of natural decay of radioactive substances will take a long time, particularly if combat radioactive substances are used by the enemy.

The decay of radioactive substances cannot be accelerated; they cannot be neutralized and, consequently, their activity cannot be lessened by any physical or chemical methods.

The only method of lowering the degree of contamination by radioactive substances consists in removing them mechanically from the surface of objects and from the human skin.

To preserve the combat capability of units active in a contaminated area, measures aimed at protecting them against contamination by radioactive substances are of the greatest importance. Therefore, radioactive substances must always be removed from clothing and the skin as quickly as possible. /216

Removal of radioactive substances from the skin and the conjuctiva, as well as from the mucous membranes of the nose and oral cavity, is called decontamination. This represents one of the most important measures for protecting troops against contamination by radioactive substances.

Depending on the combat conditions, decontamination can be partial or complete.

Partial decontamination of the troops is organized in the smaller units as early as possible without distracting the troops from the fulfillment of their military task. The treatment may be carried out in the contaminated area or after the troops have left the district.

In the course of partial decontamination, the exposed parts of the body (face, legs, hands) have to be washed with uncontaminated water from a flask or an uncontaminated source (e.g. a spring). If uncontaminated water is not available or if it is insufficient, partial decontamination can be carried out by repeated rubbing of the exposed parts of the body with cotton-wool or gauze swabs, towels or handkerchiefs, moistened with water from a flask. If no water is available, the exposed parts of the body must be rubbed with sterile dry swabs. In extreme cases any material at hand - grass, leaves, etc., outside the contaminated area can be used to rub the uncovered parts of the body. In winter, uncontaminated snow can be used for the same purpose.

The exposed parts of the body must be treated by rubbing them in one direction, from top to bottom. During this process the swabs must be turned over continuously. The rubbing of the body must be carried out without too much effort, to avoid rubbing the radioactive substances into the skin or the formation of fissures in the skin. Repeated treatment of one and the same part of the skin must be carried out with the clean side of the swab or a fresh swab.

After treatment of the exposed parts of the body, the hands must be thoroughly dried and the mouth must be rinsed with pure water. During the washing of the face with liquid taken from the personal chemical defense kit, the eyes, nose and mouth must be firmly closed to avoid the liquid getting into these organs and thus to prevent irritation of the mucous membranes.

Special attention should be paid to the thorough cleaning of /217
those parts of the body which, at the moment of explosion of an atomic weapon, were unprotected by a uniform or anti-chemical clothing. In the first instance visible drops and dust must be removed with dry or slightly moistened swabs. Then, the hands and neck must be wiped as well as the front part of the gas-mask, if the latter was worn. However, if for some reason the gas-mask was not worn during the atomic explosion, the front and the inside of the mask must be wiped, then the mouth must be rinsed several times with pure water from a flask and the mask put on.

After evacuating the contaminated area, a more thorough partial decontamination can be carried out if circumstances permit. For this purpose the protective overcoats must be taken off, the uniform must be given a good shaking, the slippers, gas-mask and protective clothes must be taken off, then the uncovered parts of the body must be washed two or three times with pure water, and the mouth rinsed. If there is time and if pure flowing water or a large reservoir is available, bathing should be organized.

Partial decontamination is usually carried out both before and after the partial decontamination of weapons and equipment. Repeated decontamination has the purpose of removing radioactive substances which have come into contact with the skin and the mucous membranes during the decontamination. Thorough partial decontamination reduces to a considerable extent the danger of injuries caused by radioactive substances.

When carrying out partial decontamination of an affected area, the individual chemical protective clothing must not be taken off.

Usually, full decontamination is carried out after completion of a combat assignment. It consists in removing radioactive substances from the whole body, the conjuctiva, the mucous membranes of the nose and the oral cavity, and washing under a (preferably hot water) shower, or in uncontaminated natural water. Full decontamination is carried out in bathing and decontamination bays, organized specifically for that purpose outside the contaminated areas. In towns and villages, public baths, disinfection stations or shower baths can be used for the decontamination. Under field conditions, showers mounted on trucks, basins, barrels or buckets can be adapted for this purpose.

In summer, decontamination areas can be equipped with tents or light curtains; in winter with heated tents. /218

On arrival at the washing-decontamination point, first of all the equipment, weapons and uniforms are decontaminated and then the people are directed to the decontamination bay. This bay consists of three sections: one for undressing, one for washing and one for dressing. In the section for undressing, the people undress and are thoroughly checked dosimetrically to establish the degree of contamination of the uniform, equipment, underclothes and the skin. Here the dosimetrist indicates which parts of the body require particularly thorough washing. Uniforms contaminated to a considerable extent are taken away for decontamination. After decontamination, the uniforms and equipment are brought by special carriers to the dressing section. If the uniforms are contaminated below a certain level, or not contaminated at all, they are transferred directly to the dressing section.

Persons who have scratches and fissures on the skin are provided with dressings while in the washing area.

From the undressing section, the people are sent to the bathing section where they are given soap and a face towel; they wash under the supervision of a nurse.

Compared to other parts of the body, the degree of contamination of the hands is usually the highest, and dirt remaining under the nails and containing radioactive substances may cause severe injuries of the nail-bed; also, radioactive substances which remain under the nails can later enter the mouth and other parts of the body. For this reason it is desirable to begin with washing thoroughly the hands and removing the dirt from under the nails, then the head, face and neck must be washed two or three times with soap. Hair, eyes and ears must also be thoroughly washed, since in these places a considerable quantity of radioactive substances and dust may accumulate. Then, the mouth must be rinsed several times with water, the whole body must be washed, paying particular attention to hairy parts and, finally, the whole body must be cleansed with pure water. The duration of washing under the shower is 10 minutes and, if the bathing is carried out from buckets, 15-20 minutes.

When the people leave the bathing section, the dosimetrist checks the thoroughness of the decontamination. If the degree of contamination of the skin is below a certain level, they are sent into the dressing section where they put on their clothes. If, however, the degree of contamination of the skin proves to be in excess of the permissible limit, the persons in question are sent back to the bathing section to repeat the treatment. In those cases in which repeated washing does not lead to positive results, the contaminated persons are admitted for medical observation. /219

In the dressing section, temporary dressings which have been applied to lesions of the skin are removed and those persons who have red eyes or discharge tears, or who complain of photophobia wash their eyes (with 2% soda solution).

All the people must bear in mind that thorough decontamination carried out in time is a very important measure in the prevention of injuries caused by radioactive substances.

CHAPTER XIII /220

SANITARY TRAINING

Sanitary training includes the teaching of the principles of personal and collective hygiene and application of self-aid and mutual aid on active service or in the case of accidents to the crew, non-commissioned officers and the cadet corps of the Soviet Army. The sanitary training of the troops includes: personal hygiene of a soldier (cadet), barrack hygiene, prevention of infectious diseases, prevention of intestinal diseases, rendering of self-aid and mutual aid in battle, rendering first-aid in the case of accidents and prevention of colds.

The teachings of sanitary training discussed in this book are essential for cadets in order to raise the general hygienic standard and also for their further practical training as commanders and instructors of soldiers and petty officers.

Personal Hygiene

The personal hygiene of a soldier is based on regulations derived from scientific and practical experience and on behavior in everyday life aimed at the preservation and improvement of health, development of physical strength and endurance of each member of the army, and increase in the fighting capacity of the military units.

By personal hygiene we understand observation of cleanliness of the skin of the face, hands, legs, hair, hardening of the body, prevention of sores or sweating of the limbs, and frostbite. Correct observation of the laws of personal hygiene is of advantage to the whole military community, since private and communal life in a military unit are indivisible. Failure to observe the laws of personal hygiene frequently leads to illness which may spread and, consequently, may interfere with the training and combat activity of the whole squad or even unit. The /221 Standing Orders of the armed forces of the USSR attach great importance to the laws of personal hygiene and it is the duty of commanders and leaders of all ranks to guard the health of the men under their command and to ensure that they observe the laws of personal hygiene.

Strict adherence to these laws is compulsory for all, without exception, and particularly for persons who work in kitchens, canteens, food stores, and water-sterilizing equipment in military settlements, camps, airports and so on. Any infringement of the laws of personal hygiene by these people may have severe consequences for the whole military unit.

For this reason a conscientious attitude by each member of the army towards the observation of the laws of personal hygiene is of great importance.

Daily, early morning, inspection of all servicemen to see that the laws of personal hygiene are observed (condition of the feet, socks, shoes, uniform and underclothes as indicated in the Standing Orders), can and should serve for accustoming the serviceman to good habits and this should lead to a better knowledge on how to keep healthy and fit.

The most important element of personal hygiene is care of the skin.

The skin - the external cover of the body - is of complicated structure. It contains a great number of nerve endings which receive stimuli from outside and connect the skin with the central nervous system. The skin carries out a variety of functions which play an important role in the vital activity of the body. The skin defends the body against various obnoxious external factors and against the infiltration of pathogenic micro-organisms into the body. The superficial (horny) layer of the skin is of acid reaction and consequently represents an unfavorable medium for the multiplication of micro-organisms, and the horny scales shed by the skin remove micro-organisms mechanically from the surface of the skin. The skin, which has a very large number of very small blood vessels and nerve endings and has close contact with the central nervous system, takes part in heat exchange, particularly in the removal of heat from the body. It receives various stimuli from the outside (thermal, pain and tactile sensations) and also takes part in the metabolism of the body. The fat /222
present in the skin renders the superficial layer of the skin elastic.

The skin contains a great number of nerve endings, which receive stimuli of all descriptions originating from the ambient medium (heat, cold, etc.) and transmits them to the brain. In the brain, reactions arise in response to these stimuli which are then transmitted along the nerves to the skin (the skin becomes pale, or red, and so on).

The cleanliness and hardening of the skin are very closely interconnected. Observation of the laws of hygiene will also result in improved hardening of the skin, and all such measures aimed at hardening are effective only if the cleanliness of the skin is carefully maintained. The cleanliness and hardening of the skin determine to a considerable degree the health and toughness of the whole body.

The more perfectly the skin is cleansed of dust, dirt, sweat and shedded horny scales from the surface layer, which mainly accumulate in the folds of the skin, under the nails and between the toes, the more active the vital function of the skin and the easier is prevention of virulent and other diseases of the skin. This leads us to the main requirement of personal hygiene: a daily wash with soap and water of the uncovered parts of the body, i.e., the hands, face, neck, eyes, ears, the armpits, legs, and a bath or warm shower at least once every ten days.

Personnel who work in kitchens, canteens and bakeries (chefs, bakers), as well as those who work in workshops and out of doors, should have a warm shower after their daily work.

These hygienic measures, together with a daily cold foot-bath, improve the vital activity of the whole body and toughen it.

Most frequently, the hands become contaminated. Contamination of the skin is dangerous from the point of view of infection during the preparation and consumption of food. A person who touches his eyes, face, lips or objects which are later taken into the mouth (mouthpieces, cigarettes, toothbrush) with dirty hands, may transmit infectious diseases through his hands; such severe diseases as dysentery or enteric fever are rightly called "dirty hand diseases". Contamination of the skin in latrines is particularly dangerous. For this reason thorough washing of the hands with soap is compulsory, not only in the morning and at night, but also before each meal and after each visit to the toilet.

Great attention should be paid to the cleanliness of the skin under /223
the nails. The dirt under the nails frequently contains pathogenic micro-organisms as well as the eggs of helminths. For this reason, nails should always be cut very short and hangnails on the side of the nails must also be cut off. Washing the hands with gasoline, as is frequently done at airports and in certain workshops for aircraft repair, must be categorically forbidden.

Care of the feet is also of great importance. Colds are mostly due to wet footwear and cold feet. People who wash their feet daily in cold water and thus harden the skin of the lower extremities will be less likely to catch a cold or a chill if their feet get wet, which is sometimes inevitable during military duties. If footwear and boots do get wet, they must be dried as soon as possible, certainly on the same day.

Daily washing of the feet with cold water is also a means of preventing perspiration, frostbite and sores. If the feet sweat the skin becomes moist, just as when the boots or socks become wet. This increases the conductivity of heat and consequently one of the main protective mechanisms of the body, the heat regulation, is impaired. The sweat secreted by the skin has an unpleasant smell and pervades the indoor air.

Soldiers in their first and second year of service must have their hair closely clipped at least twice a month. For shaving, personal razors and brushes should be used, observing all relevant hygienic rules (washing the face before shaving, using clean shaving equipment, using a sharp razor, and using eau de cologne or hot water after shaving instead of alum or creams).

Teeth, the function of which is to chew food, facilitate the assimilation of the food (digestion) by the body. Loss of teeth makes the chewing of food more difficult and increases the development of gastric disorders. Bad teeth may cause agonizing toothache, periostitis in the jaws, and development of chronic foci of infection, from which foci organisms may enter the blood and cause a number of general diseases. For this reason care should be taken to preserve one's teeth. Teeth should be cleaned twice daily (morning and evening), but at least in the evening, with a stiff toothbrush and tooth-powder or paste, then the mouth should be rinsed to remove scraps of food. Particles of food which have become stuck between the teeth can also be /224 removed with the aid of a toothpick or a sharpened matchstick, but never with a hard metallic object.

The drinking habits which are connected with the hardiness of the crew in summer represent an important aspect of personal hygiene. Haphazard and frequent drinking of water in hot weather does not quench the thirst, as liquid introduced in this manner into the body does not stay there but causes only profuse sweating which weakens the body. A trained soldier can tolerate loss of water up to 1.5-2 or even 2.5 liters without impairment of his working capacity.

Correct training with regard to drinking habits performs two important tasks: it increases endurance and prevents the development of gastro-intestinal disorders. An untrained soldier having exhausted the water from his flask will sometimes endeavor to quench his thirst from any source of water, even if it is contaminated.

Snow should never be used to quench thirst since it may be contaminated by excretions and the urine of various animals. Besides, micro-organisms may live for a prolonged period in snow and ice and, after entering the human body, may cause diseases.

Bodily hygiene is inseparable from physical culture and toughening of the body. Systematic and conscientious toughening trains the body, preserves health and increases the stamina, strength and endurance of the serviceman.

A serviceman who is fit and well trained for operations under various conditions will tolerate more easily great heat or cold and is less likely to suffer heat stroke, frostbite and chills. Such a serviceman will be able to withstand greater difficulties during training or battle.

Barrack Hygiene

Barracks is the name of the premises intended for the accommodation of military units. They should be kept properly clean and orderly. Cleanliness of the premises and air in barracks is vitally necessary for the preservation of health of the servicemen living in them.

The layout of the rooms and internal facilities in the barracks of the Soviet Army and the Standing Orders have been carefully planned to /225
facilitate observation of hygienic requirements.

All the living and other accommodations in the barracks are assigned to the various sections by the commander of the unit and must be used for precisely the purpose laid down in the Standing Orders. According to these Standing Orders of the Armed Forces of the USSR, each company must have a dormitory, a room for political and other education, a room for office work, a room for the cleaning of weapons and a number of auxiliary rooms: a storage room for the property of the company and for personal property, wash-rooms, a room for the cleaning of boots, for smoking, lavatories and drying rooms.

Auxiliary rooms within the barracks make it possible to secure proper cleanliness in the sleeping quarters and lecture rooms.

The largest area within the barracks is usually assigned to the quadron personnel. In the sleeping quarters, beds must stand in rows appropriate to the floor area at a distance of at least 80 cm from the windows or the external wall. Lockers are placed between the beds at the head end; they serve for storage of toilet articles and other permissible personal possessions. Men must maintain exemplary order in their lockers and they must be systematically checked by the commanders.

Uniforms should be neatly folded and placed on stools and boots should be put at the foot of the bed when taken off at night. Every morning after reveille, beds should be made properly.

Overcoats, fur coats and headwear should be hung on hangers in places assigned for the purpose; working clothes should be kept in the special cupboards outside the sleeping quarters.

Weapons and entrenching tools should be arranged in pyramids; they are usually placed in the corridors along the walls so that they are easily accessible. Ammunition and gas-masks should be kept in cupboards.

In the men's quarters there should be barrels containing drinking water which should be under lock and key. The water in the barrels should be changed daily by the men on fatigue duties under the supervision of Medical Officers. /226

Harmful insects such as bugs, cockroaches, etc., must not be tolerated in the barracks. If such insects are discovered, immediate extermination must be carried out.

To prevent dirt being brought into the living quarters, metal grids or rugs and mats or iron scrapers should be placed at the entrance; in the rooms set aside for cleaning boots and clothing, brushes must be provided.

Daily cleaning of the barracks in accordance with regulations is part of the fatigue duties. To prevent the contamination of air by dust, the floors, walls, windows, doors, weapon-stands, clothes hangers, stoves and other objects should be cleaned with damp cloths and the rooms must be aired.

The rooms within the barracks must contain an adequate number of spittoons and urns. These should always be clean and should be systematically emptied. Particular attention should be paid to the cleanliness of the lavatories, the smoking rooms and wash-rooms, as well as the rooms used for the cleaning of weapons.

Once a week, general cleaning of the whole premises, including compulsory washing of the floors, should be organized. In winter, the stoves must be lit during this cleaning; in summer, the windows must be opened so as to accelerate drying out of the premises. During the cleaning operations, bedding must be carried out of the premises, beaten and aired.

Under barrack conditions, ventilation of the rooms is of particular importance. As has been said above, the composition of the expired air is quite different from that of the inspired air; it contains a considerable quantity of carbon dioxide. Hence, in the absence of an influx of fresh air, the breathing of the occupants will bring about an increase of carbon dioxide in the barrack air.

The air may also be fouled by perspiration and moisture evaporated from clothing and shoes while they are being dried.

Prolonged stay of people in a room with fouled air lowers the well-being, causes headaches and reduces working ability. This means that if the quarters are completely isolated from the external atmosphere, conditions in the barracks soon become unpleasant or even

6

intolerable for human beings. Usually, however, no marked decrease in the oxygen content and no marked increase in the carbon dioxide content of the air can be observed in the living quarters. This is due to the continuous ventilation of the premises. /227

We distinguish between natural and artificial ventilation: by natural ventilation is understood the exchange of air between the premises and the ambient atmosphere through the walls of the building (by virtue of the latter's porous character) as well as through the fissures in the doors and windows. The natural influx of fresh air is usually insufficient; particularly where the quarters are crowded. The influx of air will further decrease if the walls are painted with oil paint or tiled. For this reason, natural ventilation is usually supplemented by artificial ventilation consisting of systematic airing of the premises through ventilation channels, small hinged ventilating windows, fixed ventilating frames or open windows.

Standing Orders stipulate compulsory airing of the barracks in the absence of occupants. The dormitories should be aired during the physical-exercise period, after the rest hour and before going to bed. The dining halls should be aired after breakfast, lunch and supper; lecture halls before lectures, during intervals and after lectures. All rooms must be aired by the man on duty under the supervision of the duty officer. When people are present, ventilation should be from one side only to exclude draughts. Lavatories, rooms used for the cleaning of weapons, smoking rooms and staircases must be aired particularly thoroughly.

Systematic ventilation of barracks not only ensures adequate oxygen for respiration but also prevents diseases developing.

Ventilation can be intensified considerably by lighting stoves.

A common dutch stove will remove up to 100 m^3 of air per hour from a room. It is advisable to heat the rooms with the small hinged windows open; this will prevent inflow of stale air from neighboring rooms.

The charging of stoves in living quarters should be terminated not later than 20.00 hours and in classrooms and service rooms one hour before they are to be used. At times of severe frost and on days when floors are washed, the stoves should be lit twice a day.

Drying of fuel near the stove, storage of fuel in the living quarters, as well as the sawing and chopping of wood on the premises, must be strictly prohibited.

Any heating system is acceptable from a hygienic point of view if it ensures maintenance of an even and stable temperature between 16 and /228

$18^{\circ}C$, whatever the weather. Central heating is the most satisfactory: there is little danger of fire, it does not cause dirt and dust and does not contaminate the air.

The lighting of barracks is of great importance for maintaining good health conditions. Adequate lighting improves the working ability of the occupants and keeps their spirits up. Satisfactory natural lighting depends on many factors, including the size and cleanliness of the windows, the distance between the walls and adjacent buildings, etc. Dirt, dust or soot on the windows and the walls lowers the level of lighting of the premises by 15 to 50%. Unsuitable interior decoration, e.g. dark wall paint, dirty walls, etc., lowers the level of lighting to a considerable extent. Soot on the ceiling can reduce the level of lighting by one-third. The brighter the wall paint the less will be the light absorbed by the walls and the more will the light rays be reflected.

Of artificial sources of light, electric light is the best as it gives an even white light which does not flicker as does the weak yellow light from candles or paraffin lamps which consume oxygen and foul the air. It should be borne in mind that dirty bulbs and lampshades cause considerable loss of light. A well-washed and dried electric bulb of 16 candle power will give 30-32% more light than a dirty one.

It is obvious from the above that clean bulbs, walls and windows are of hygienic importance; therefore, they must be thoroughly wiped during the daily cleaning. Dust must be removed with particular care since it contains a large quantity of dangerous micro-organisms.

The Soviet Government pays a great deal of attention to the satisfactory construction of barracks. In these, conditions are provided for the preservation of the good health of the servicemen, thus ensuring successful training for combat and political education. In addition to providing satisfactory general conditions, care must be taken to ensure compliance of all servicemen with the rules of hygiene.

For this reason every serviceman must strictly observe all rules of personal hygiene: clean his boots from dirt and dust, not spit on the floor, not spread litter and only smoke in the rooms set aside /229 for this purpose, not lie on the bed in uniform and maintain order and cleanliness in the washrooms, lavatories and other communal rooms.

Adequate observation of the rules of hygiene in the barracks by every serviceman and the whole unit will preserve the health of the unit; this is an important condition for maintaining a high combat-readiness of service.

Diseases Caused by Cold and Their Prevention

Chilling of the body can cause various ailments such as: acute catarrh of the upper respiratory tract (inflammation of the mucous membranes of the nose, larynx and Highmore cavities), some types of influenza, tonsillitis, neuro-muscular ailments, etc.

Although all the conditions enumerated above are connected with colds, it has been shown that infection plays an important part in their development.

In all cases of colds the resistance of the body decreases, which enhances the infiltration and propagation of organisms causing disease. The reduced bodily resistance during a cold is due to lack of adequate toughening-up.

It has been observed that diseases caused by cold frequently arise after prolonged parades in the cold without an overcoat, open-air exercise in winter immediately after taking a bath, singing in the open air at low temperatures, etc.

Of no less importance is failure to observe the rules of hygiene in the housing of servicemen and heating arrangements, particularly ventilation of premises, i.e. insufficient number of drying facilities, etc.

The majority of ailments caused by colds are, as a rule, of short duration and end in complete recovery. The occurrence of these ailments, nevertheless, is very serious, not only with regard to their frequency but also because of the time lost by absenteeism. Hence, it is of paramount importance that all servicemen should be familiar with the nature of colds and with preventive measures.

Acute Catarrh of the Upper Respiratory Tract

Sharp fluctuations in the external temperature and chilling of the body play an important part in the development of acute catarrh in the upper respiratory tract. /230

Some forms of acute catarrh of the upper respiratory tract can spread by contact-droplet infection and lead, in crowded quarters, to focal outbreaks.

Acute catarrh of the upper respiratory tract usually begins with inflammatory symptoms in the nose, throat, nasal pharynx and gradual rise of temperature.

The rise in the body temperature is usually slight and the latter rarely reaches 39°C. A running nose, difficulty in breathing through the nose, pain on swallowing and coughing are further characteristic symptoms.

Simultaneously, the patient complains of headaches, shivering and pain in the limbs; a characteristic rash can be observed around the mouth and on the nose.

The raised temperature persists for 1-3 days and then returns to normal.

Influenza. The cause of influenza is a filtrable virus. Infected persons are the natural carriers of the virus. The disease is transmitted by airborne droplet infection. The patient disseminates the virus when speaking, coughing or sneezing.

Influenza begins with sudden shivering, followed by a rise in temperature within the next few hours; the symptoms reach their peak within the first day. The patient complains of headache, mainly over the eyebrows, lack of appetite, poor sleep, depression, rheumatic pain all over the body and the extremities. Simultaneously, hyperemia of the skin on the face and the conjuctiva, hyperemia and dryness of the mucous membranes of the throat, sweating and head colds can be observed.

Uncomplicated cases of influenza last from 3-5 days. In the course of the first few days the temperature rises to a high level then it decreases gradually and reverts to normal on the third, sometimes but less frequently, on the fifth, day of the illness; general weakness, sweating and increased excitability of the nervous system persist for several days after the fall of the temperature.

Tonsillitis. Tonsillitis can develop whenever the causative organism penetrates the mucous membrane of the throat. /231

A sore throat (spontaneous pain and, particularly, pain on swallowing, most frequently on both sides) as well as an enlargement of the tonsils are characteristic of tonsillitis.

Tonsillitis is, as a rule, accompanied by high temperature which decreases only slightly in several days; at the same time, the patient complains of weakness and aches, shivering, pains in the joints and other symptoms.

Tonsillitis usually takes an acute course. The symptoms become rapidly intensive, reaching their peak within 2-3 days and subside again just as rapidly. The whole illness lasts, as a rule, not more than a week.

Nerve and Muscular Ailments Caused by Colds

Nerve and muscular ailments caused by colds include disorders affecting the peripheral nervous system, particularly in the lumbar and sacral region (sciatica, radiculitis) as well as ailments of the muscular system (so-called "myositis"). These ailments occur most frequently in winter. Myositis ranks as an independent disease or as a complication after influenza, tonsillitis and others.

Most frequently, myositis can be observed in the muscles of the neck, small of the back and the chest muscles. The affected muscles are tender on palpation and movements are impossible or considerably retarded.

The Prevention of Ailments Caused by Colds

Toughening-up of the body is one of the most effective means of increasing the resistance and, consequently, of preventing such ailments.

Toughening-up is effected by measures aimed at increasing the resistance of servicemen to harmful influences of their environment (cold, heat, sharp fluctuations in temperature).

Physical exercises and some other pursuits, as well as spare-time occupations should include special measures aimed at toughening-up. /232
All these should be carried out under medical supervision.

The individual commanding officers should organize the toughening-up of servicemen according to a plan compiled by the physical-training officer with the participation of the medical officer.

The following are the basic measures aimed at the toughening-up of servicemen; these should be carried out throughout the year:

- daily morning physical exercises in the open air, wearing light clothing;

- daily ablutions with cold water with the body bare to the waist and, after a sufficient degree of toughening-up has been achieved, cold showers or baths;

- washing legs and feet with cold water before going to bed;

- ski training and marching in winter without overcoat, exercises lasting up to 3 hours at air temperatures down to -15-20°C in the absence of wind;

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- various large-scale sporting exercises and some other types of physical training in summer in light uniform or trunks;

- on warm sunny days certain exercises and occupations should be carried out without coats, in shirts or with a bare chest;

- gradually increasing physical exercise in the heat of the day;

- systematic air- or sun-bathing in spare time or on Sundays.

All measures aimed at toughening-up should be carried out systematically, gradually increasing the intensity of the process from milder to stronger toughening-up; during this process attention should be paid to special features in the physical condition and degree of toughening-up of individual servicemen and it is also necessary to take into account local climatic conditions.

In addition to the comprehensive measures aimed at toughening-up servicemen, the following measures are also of great importance in the prevention of ailments caused by cold:

- strict observation of the rules concerning the equipment and facilities of living quarters;

- proper and regular washing and cleaning of living quarters, ventilation, dusting furniture and cleaning bedding.

- maintenance of uniform and footwear in an immaculate condition /233
and timely drying of wet clothing;

- boiling of dishes in canteen;

- observation of personal hygiene;

- detection and removal to sick bay or hospital of people suspected of suffering from ailments caused by a cold;

- periodical preventative disinfection of the living quarters;

- disinfection of the premises after isolation of patients.

Infectious Diseases and Their Prevention

Diseases transmitted from sick persons to healthy people are called infectious diseases. The danger consists of the fact that they can instantaneously or within a relatively very short period affect a great number of persons.

There were times when the causes of infectious diseases were not known and it was impossible to combat them efficiently. At that time, infectious diseases spread widely, causing the death of a considerable proportion of the population. For instance, in the fourteenth century about 25 million people died of the Plague in Europe. Similar losses were suffered at the same time in Asia.

Even in the eighteenth century plague occasionally used to decimate whole districts.

Smallpox also claimed an enormous number of human victims. In the seventeenth century smallpox was the most widespread and most dangerous illness and caused the death of over 50 million people.

The development of science provided humanity with an increasing number of new means of combating infectious diseases. However, even in the twentieth century, infectious diseases are very widespread in capitalist countries, although not to the same extent as in the past. (Translator's note: sic.)

In 1918 and 1919, influenza, then called "Spanish flu" was widespread in almost all countries of the world. Within two years this infectious disease caused the death of 20 million people, i. e., much more than the number of victims, of all the armies taken together, who died on the battlefield during the four years of the First World War.

War has always enhanced the spread of infectious diseases. Up to the twentieth century statistics have always shown that troops suffered greater losses due to infectious diseases than to enemy action. For /234
instance, according to the scientist, Kolb, European wars between 1733 and 1865 (133 years) caused more than 8 million victims out of which 1.5 million died of their wounds and 6.5 million of infectious diseases.

Only in the twentieth century after science had devised new means of preventing infectious diseases was there a decline in infectious diseases among the fighting forces.

In the USSR intensive measures are taken against infectious diseases. Since the emergence of the Soviet regime, numerous diseases which were rampant in Tsarist Russia have been completely eradicated. These include plague, smallpox and cholera.

Commanding officers and the whole medical service of the Soviet army take constant care of the health of servicemen. However, the maximum success in combating infectious diseases can be achieved only if every serviceman understands the importance of the rules he is required to observe in order to protect himself and his comrades against infectious diseases.

It must also be borne in mind that in the case of war the enemy might well use bacteriological weapons which may bring about a great danger of large-scale spread of infectious diseases.

The Causes of Infectious Diseases

Infectious diseases are caused by microscopic living organisms invisible to the naked eye. These small living organisms are called microbes. Some microbes are so small that they cannot always be seen even with the aid of modern electron microscopes.

Investigations have shown that out whole environment is populated by microbes. They can be found in the air, in the soil, in water and on the surface of various objects. A great number of microbes also occurs on our skin, in the oral cavity and in the gastro-intestinal tract. All micro-organisms can be divided into two large groups: those which are useful and those which are harmful to the existence of human beings. The first group includes nitrogen bacteria, micro-organisms which are of /235 great importance in agriculture, as well as micro-organisms causing fermentation, etc. The second group includes all those micro-organisms which cause infectious diseases.

Different infectious diseases are caused by different types of micro-organisms. The latter organisms are of various shapes and have a number of features which enable us to discriminate one type of micro-organism from the other.

The micro-organisms are capable of multiplying very rapidly in the human or animal body by way of division. Within 15-30 minutes two microbes can develop from one. It has been calculated that one microbe, even if it divides into two in the course of an hour, will form 16.5 million microbes in the course of a day provided it finds sufficient nutritional material in the host's body.

Microbes contain special poisons, so-called bacterial poisons or toxins. When micro-organisms multiply in the human body these poison the whole body and above all the central nervous system, causing illness.

In various diseases, infection is transmitted in different ways. There can be direct and indirect transmission. In case of direct infection, the disease is transmitted directly from an infected to a healthy person, for instance, while talking, coughing, sneezing, etc. This is the so-called droplet transmission. When a person speaks or coughs, small droplets of saliva are spread over a wide distance. These droplets fall together with microbes upon clothes, face, and hands of exposed persons. From here the microbes are transferred in one way or another to the mouth, the stomach, the lungs and the blood where they cause the illness.

Micro-organisms causing infection may enter the lungs together with the air; from here they can be resorbed into the blood where they can cause illness.

In the second case, human beings are infected, not from the infected people themselves, but from objects used by them, including objects which they had used a long time ago which were not disinfected. Infection through water, food, raw fruits, vegetables, etc., may serve as examples for this type of infection. For certain diseases this method of spread is highly characteristic. This refers primarily to gastro-intestinal diseases (enteric fever, paratyphoid, cholera, dysentery).

Infectious Diseases of the Gastro-Intestinal Tract /236

The infectious diseases of the gastro-intestinal tract include enteric fever, paratyphoid, cholera and dysentery. These diseases can be united in a common group as they have a number of characteristic common features. The type of transmission and the spread of these diseases are very similar and so are the measures against them and the methods of their prevention.

Contagious gastro-intestinal diseases are contracted whenever organisms causing these diseases enter the gastro-intestinal tract with contaminated food or water. Open waters - rivers, lakes, ponds - are frequently contaminated by sewage water from inhabited areas or by the washing of dirty linen or from the watering or bathing of domestic animals. Water of this kind should, consequently, always be regarded as unsatisfactory from a sanitary point of view. These waters should never be drunk in a raw state. Water of shallow wells situated near horses' stables, dumping grounds, refuse collections or lavatories can also be contaminated through the soil (the sewage may seep through the soil into the well). The most frequent pathway of infection is the so-called water-borne infection. Transmission by means of contaminated foods takes second place among the ways of spreading infectious diseases of the gastro-intestinal tract: in this case infection may be due to the consumption of unwashed and unboiled food products contaminated with micro-organisms, e.g., milk, vegetables, etc. Raw as well as cooked foods can be contaminated by flies and the hands of the cook - if the latter has failed to comply with the rules of hygiene. Food can also be contaminated when prepared on dirty tables in unwashed dishes or due to the use of dirty kitchen equipment. Touching of food products with dirty hands may also lead to intestinal infections.

Epidemic gastro-intestinal diseases can also be spread in yet another way. This is the so-called contact infection in which case infection takes place by direct contact with the infected person or bacteria-carrier, i.e., the person who is not ill himself but discharges organisms into the ambient medium in his stools or urine.

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Enteric fever. This acute infectious disease, which can occur in isolated cases, may also lead to widespread epidemic outbreaks. The causative organism of enteric fever is a microbe which can be found in the stools, the blood and the bile of patients. This organism may persist in the soil up to six months and in infected cadavers up to three months. In water, this organism remains viable up to five days. At a /237

temperature of 60-65^{o} C the causative organism of typhoid fever perishes within an hour. Direct sunlight kills the organism within eight hours. The usual disinfectants such as carbolic acid, lysol and naphtha-lysol kill the organism within 30 minutes.

The incubation period of enteric fever is 8-21 days after the organism enters the patient's body. The illness begins with a gradual rise in temperature which, by the end of the first week of the illness, reaches 39^{o} C or more.

The patient first complains of headaches, general weakness and malaise and increased proneness to fatigue. From the second week of the illness the headache becomes more intensive; the patient may lose consciousness and become delirious. The tongue is dry and furred, diarrhea frequently occurs but conversely some patients suffer from constipation. After 7-10 days of the illness, a rash appears on the skin of the chest and abdomen which rash consists of small pale pink spots which disappear when pressed with the finger.

The illness usually lasts 4 weeks. The fall in the temperature begins in the third week of the illness and, by way of gradual decrease, the temperature reverts to normal by the end of the fourth week. Enteric fever may also last longer, particularly, in case of the ensuing complications.

The most serious complications are intestinal hemorrhage and perforation of the intestinal wall. These complications usually occur between the 15th and 25th day of the illness, they are highly dangerous and may cause the death of the patient. In this period patients require absolute rest and particularly careful mursing. Transport of patients during this period should be strictly prohibited. Severe complications occur more frequently in those cases in which the parient fails to observe the rules of diet during illness and particularly during the period of convalescence. Enteric fever is a severe illness which exhausts the patient and renders him incapable of working for a considerable period.

Convalescents from enteric fever may for a long time discharge enteric-fever rod-like organisms with the stool or urine. These people (bacteria-carriers) must be kept under strict medical observation as they

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are potentially one of the most frequent sources of infection of healthy people.

Paratyphoid fevers. These fevers are at present divided into two groups of different characters. The first includes Paratyphoid A and B which cause in man diseases similar to enteric fever but different in that they take a shorter and milder course. The second group includes paratyphoid fevers which lead to symptoms of acute food-poisoning. /238

Paratyphoid A occurs only in some districts of the USSR, mainly in the south and south-east and less frequently in the central zone. Cases of Paratyphoid A are hardly different from Paratyphoid B with regard to their character and course. The difference between these two conditions can be established only by pathological investigation of the blood. Cases of Paratyphoid A are most frequently transmitted by contact infection from patients or bacteria-carriers.

Paratyphoid B occurs fairly frequently in the form of epidemic outbreaks. The illness is most frequently transmitted by contact with patients or bacteria-carriers. Infection transmitted by food occurs most frequently when the microbes find their way into cooked food if the preparation and distribution of the food is carried out by a cook or some other person who is a bacteria-carrier.

The rod-like organisms causing Paratyphoid B can easily multiply in milk. For this reason, consumption of raw milk presents one of the most frequent causes of the spread of Paratyphoid B.

Water-borne infection with Paratyphoid B occurs fairly rarely. Paratyphoid B runs almost the same course as enteric fever and lasts about two weeks usually ending with recovery.

Food poisoning. The second group of paratyphoid fevers includes those which lead to acute poisoning occurring within 4 to 6 hours after the consumption of food contaminated with the causative organism of the paratyphoid fevers in question. This organism can frequently be found in the intestines of cows and pigs and may enter the muscles (meat) while the animal is still alive if it was exhausted or suffered from some acute disease. The organisms of the paratyphoid group can also enter the meat during slaughter of the animal or during the processing of the carcass by contamination through flies, rodents, dirty hands of the cook or in some other manner. If meat is stored for a prolonged period in a warm place the organisms of the paratyphoid group can multiply and can discharge poisons (toxins). If this meat is then inadequately cooked, its consumption by human beings can lead to food poisoning. Organisms of the paratyphoid group can also be found in fish, consumption of which may lead /239
to food poisoning.

Severe abdominal pains, nausea, sometimes vomiting, frequent diarrhea and general weakness are characteristic symptoms of food poisoning

17

caused by meat or fish contaminated with organisms of the paratyphoid group. The illness lasts 1 - 2 days.

Dysentery. Dysentery or bloody diarrhea (a disease of the large intestine) can occur in two forms: bacilliary dysentery caused by bacilli (rod-shaped organisms) and amoebic dysentery caused by amoebae, which are very simple organisms (protozoa) - parasites of a special unicellular type with a nucleus.

Bacillary dysentery. The causative organism of bacillary dysentery is a short rod (bacillus) occurring in several variants.

The dysentery bacilli inhabit the lower parts of the large intestine and can be found in the stools of patients suffering from dysentery. They enter the intestine with food or water contaminated with the organisms.

In milk or dairy products, the dysentery bacilli may remain visible up to 24 days, in vegetables and foods up to 11 days and in water up to 8 days. The illness begins within 2 - 9 days (on the average after 3 days) after the infection. It becomes manifest in abdominal pain, frequent liquid bowel motions, headaches and general weakness. The temperature frequently rises to 39.5 - 40° C. The tongue is dry and furred. Initially, the stools have the usual appearance of liquid stools; soon, however, they are streaked with mucus and traces of blood. The number of bowel motions gradually increases and reaches sometimes up to 50 per day. The discharge soon loses the chacter of stools and only sanguineous mucus sometimes containing pus is discharged from the intestine; frequently, the stools resemble water used for the washing of meat. The abdominal pains become more intense and spastic cutting pains or colic develop. Sometimes the illness lasts up to two weeks. In mild forms of dysentery the patient's condition gradually improves after the sixth or seventh day, the stools become normal, the abdominal pains subside and by the beginning of the third week the patient recovers.

In severe forms of the illness rapid toxication with the poisons (toxins) discharged by the bacilli takes place. This poisoning becomes manifest in general weakness, cardiac failure and fall in temperature. These symptoms may lead to the patient's death.

Sometimes dysentery acquires a chronic character and periods of /240
apparent recovery alternate with new exacerbations accompanied by intestinal disorders and abdominal pain. In epidemic outbreaks we may find patients suffering from mild disease and not very pronounced intestinal symptoms. These patients are usually treated as out-patients, are not isolated and may in consequence be dangerous to people around them. Great caution must be exercised when in contact with patients of this type.

Dysentery is most widespread in summer and autumn and the main contributory factors in its development are flies which breed in enormous numbers in areas of refuse collection and sewage fields. Flies transmit the infection with the soles of their feet from the sewage to food products and dishes. This fact is the most important factor in the development and spread of dysentery. Dysentery can also spread in winter, when the illness spreads among those persons who are in contact with patients or bacteria-carriers who have failed to observe the basic rules of personal hygiene: they do not wash their hands before the consumption of food and after visits to the lavatory.

Amoebic dysentery. Amoebic dysentery most frequently occurs in warm countries. In the Soviet Union, it can be found in Central Asia and in Trans-Caucasia.

The causative organism is an amoeba which in the external environment may undergo transition into a more resistant form: a cyst which is different from the amoeba in that it possesses a thicker membrane. Amoebae and cysts inhabit intestines of patients or bacteria-carriers convalescent after this disease. From these patients the cysts may enter water where they can remain viable up to 2 - 3 weeks. If a cook is a bacteria-carrier convalescent from amoebic dysentery he may contaminate food products and cooked food with the cysts.

Infection by a healthy person takes place by direct contact with /241
patients or by the consumption of water or food contaminated by cysts. The illness is characterized by severe abdominal pain and frequent diarrhea. The stools consist of pus and mucus mixed with blood. Ulcers form in the lower part of the large intestine, which fail to heal for a prolonged period. Amoebic dysentery may also lead to complications in the shape of liver abcesses.

Cholera. This illness is also called Asiatic cholera. It originates in India. Cases of cholera frequently occur in India, Iran, Afganistan and other countries. In the USSR cholera does not occur. The causative organism of cholera is an organism of a comma shape - the vibrio comma.

The vibrio comma inhabits the intestine of patients whence it can enter the external environment - the ambient medium with the stools. In water the vibrio can live for many months and in milk and dairy products up to 30 days.

Infection occurs most frequently by the consumption of contaminated unsterilized water, but infection may also be caused by direct contact with the patients as the vibrio can remain viable for several days on the linen of the patient and objects surrounding the patient and contaminated with his stools. Flies may transmit the vibrio to food products (milk, fruits, bread). A person consuming such food products may contract cholera.

The illness begins 1 or 2 days after the infection. The onset of the illness is very sudden. Severe vomiting and diarrhea appear which become more intensive from hour to hour. In cholera patients the stools acquire the appearance of rice water, vomiting becomes more frequent, cramp develops in the muscles of the limbs, the voice becomes hoarse. The patient rapidly weakens, his face becomes clay-colored, the nose sharpens, the lips are blue, the eyes are sunken, the heart weakens, the body temperature drops and in this state the patient may suddenly die. Death may occur within 8-10 hours after the onset of the illness; however, sometimes the illness can last for 2-3 days.

The Prevention of Infectious Diseases of the Gastro-Intestinal Tract

To prevent infectious diseases of the gastro-intestinal tract, both collective and individual measures must be taken.

Among the collective measures of prophylactic nature the following are of particular importance:

1. The sources of water supply should be under continuous medical supervision and should be provided with equipment to protect them against contamination. The water must be subjected to systematic laboratory investigation. Water taken from open sources (rivers, lakes, ponds) must be purified and disinfected before it can be used as drinking water. /242

2. The area in which the unit is located must be kept in a state of absolute cleanliness. Special fly-proof containers must be used for the collection of refuse. Refuse must be periodically burned; sewage and swill must be taken to special dumping grounds.

3. The preparation of food must be carried out under continuous sanitary supervision, and the food products should be of good quality. The food must be adequately cooked or fried. The cook and all other members of the kitchen staff must be kept under medical observation and should strictly comply with hygienic requirements.

4. Energetic measures must be taken to destroy flies and to prevent their propagation as well as to protect food products and dishes in the kitchen and canteen against contact with flies.

5. Patients suffering from acute gastro-intestinal diseases must be immediately isolated and hospitalized. Their former quarters, objects with which they have been in contact, their discharges, linen and uniforms must be thoroughly disinfected.

The following are the personal measures for the prevention of infectious diseases of the gastro-intestinal tract:

1. One should never drink unboiled water from unchecked sources of supply, particularly from open waters. One should drink only boiled water. If unboiled water has been put into the flask it must be disinfected with special pantocide tablets. One tablet is required per flask of water. The water can be drunk 30 minutes after the tablet has dissolved. Pantocide tablets are available from a medical orderly who keeps them in glass tubes.

2. One should never eat unwashed or uncleaned vegetables and fruit.

3. One should never drink unboiled milk.

4. Bread, sugar, biscuits and personal issue dishes (pannikin, cup, cutlery) must be well protected against contact with flies. /243

5. Before each meal and after each visit to the toilet, the hands must be washed with soap.

6. The finger nails must be cut short.

7. One should never use food left or offered by the local populace, particularly on alien territory, as these products might be of poor quality or might even have been deliberately infected by the enemy.

8. As soon as any sign of ill health appears, one should immediately consult a doctor.

Protective inoculations are a satisfactory means of preventing infectious diseases of the gastro-intestinal tract. In the course of the inoculations a certain quantity of killed organisms are introduced into the body, and this leads to the formation of antibodies against one or the other illness. The inoculations are carried out either by injection of killed micro-organisms under the skin, or by oral administration in the form of tablets or liquids.

In the Soviet armed forces, inoculations against enteric fever, paratyphoid, tetanus and dysentery are compulsory for all ranks. Inoculations against cholera are carried out only in special circumstances.

All ranks are given inoculations against enteric fever, paratyphoid and tetanus twice in the first year and thereafter annually. The first inoculation is given immediately on call-up, and the second before the unit goes to camp.

The inoculation material is injected two or three times under the skin near the lower angle of the shoulder blade at intervals of 10 days. It may be followed by a certain malaise and sometimes even by a raised temperature. This is an inoculation reaction which subsides after one day. Inoculation against dysentery can also be carried out orally with special tablets. One tablet is taken three times daily with boiled water, before meals, on three consecutive days.

Inoculations against cholera may also consist in subcutaneous injections of a special vaccine or may be administered in tablet form.

Parasitory Typhus Fevers /244

Parasitory typhus fevers are diseases transmitted to human beings by the bite of parasites - lice. We discern typhus fever and relapsing fever.

Typhus fever. This disease was in the past called hunger typhus or prison typhus since in the years preceding the Revolution, it was widespread among the population in times of famine and was a frequent guest in the over-crowded prisons. In the past, typhus was also widespread in times of war. For this reason it has also been called war typhus.

During the Russian-French war in 1812, Napoleon's army lost almost one third of its total number due to typhus. Typhus was also fairly widespread in Kutuzov's army.

The same occurred among both French and Russian troops during the Crimean War. Epidemic outbreaks of typhus also occurred among units of all armies during the first World War. In Russia, typhus was very widespread during the Civil War (1918-1921). At this time several million people suffered from typhus.

Typhus is transmitted by lice. There are body lice, head lice, and lice which get into clothes. Typhus is mainly transmitted by body lice. Body lice inhabit the folds of clothing and linen of dirty and unkempt persons who take no care in the cleanliness of their body, linen and clothing. Such people are the most frequent carriers of lice and consequently of typhus. The blood of a person suffering from typhus becomes infected 4-6 days after a louse has sucked his blood. Lice multiply by laying eggs in the hair of the body or on fibers of materials, to which the eggs are attached by a special sticky substance. After 5-6 days young lice are hatched from the eggs. Infection can take place by the bite of a louse infected with typhus, or by squashing a louse on the body of a person, in which case the squashed infected louse may enter fissures and scratches in the skin.

The causative organism of typhus are special micro-organisms which inhabit the blood and the internal organs of persons suffering from typhus, and also the intestines of lice. Typhus can spread only in the presence of lice; it begins 10-14 days after infection, with

general weakness, headache, and raised temperature reaching 40.5°C. /245

On the 5th-8th day an abundant fine rash appears on the body of the patient, and for this reason the illness has been called exanthematic typhus. The tongue is dry and covered by a reddish-brown fur. The patient is excited, or unconscious, sometimes delirious.

During this time the patient must be kept under alert observation as he might leave the hospital or jump out of the window.

Typhus is a severe illness lasting 14-16 days, after which the temperature falls rapidly and recovery ensues. Typhus is frequently accompanied by complications in the form of parotitis, bed sores, deafness, etc.

Once a person has suffered from typhus he becomes immune to further infection. Occasionally, however, recurrent cases of typhus have been reported.

Relapsing typhus. This typhus has been called relapsing fever, as it occurs in the form of separate attacks. It is also transmitted by lice.

The causative organism of relapsing fever is spirochete, i.e., an organism of spiral shape.

Spirochetes inhabit the blood and internal organs of people suffering from relapsing fever, and during the attack they can easily be seen in a drop of the patient's blood under the microscope.

The illness begins (5-6 days after infection) with a high

temperature which reaches 40°C and more, headache, weakness, and pain in the small of the back and the muscles of the lower limbs.

The attack lasts 6-8 days, after which the temperature rapidly falls to normal and the patient feels better. After some days, however, a second attack begins which is somewhat shorter and takes a much milder course. Five or six similar attacks may occur; on the average, however, there are three attacks. The patient's tongue is dry and covered by white fur; the skin is pale and sometimes has a blueish tinge; no rash can be observed.

Convalescents from relapsing fever become immune to it.

Prevention of Typhus and Relapsing Fever /246

The fight against lice is the basic measure for preventing typhus and relapsing fever.

To this end we have to:

1. Have a bath at least once in 10 days, followed by a change of personal and bed linen.

2. Keep the hair cut short.

3. Observe personal cleanliness and tidiness, keeping the uniform clean.

4. Frequently inspect linen and, when lice are discovered, immediately report this fact to the Commanding Officer to secure disinsectation.

The disinsectation consists of: shaving off all hair, washing in a bath or under a shower, change of personal and bed linen, disinsectation of the uniform as well as of the premises to which the man concerned will be sent after disinsectation. New recruits should undergo disinsectation immediately after arrival. Prior to disinsectation, recruits must be quartered separately from the others. Only after disinsectation and after F.F.I. parade can they join the rest of the personnel.

Every serviceman must comply day by day with the basic hygienic requirements and must carefully check his uniform and linen.

In Russia, where the living standards and the culture of the working populace are raised from day to day, every means is at hand to secure full eradication of typhus fevers. In the Soviet Union, relapsing fever has been eliminated, and it is now our task to prevent, by common efforts, its reappearance.

First Aid in the Case of Frostbite

Frostbite is the name of an injury caused by the action of low temperature. Prolonged cooling may cause frostbite even if the temperature does not fall below freezing point. Frostbite of this type occurs most frequently in the feet in persons forced to stand for a long time in cold water. It should be borne in mind that tight /247
clothing accelerates the development of frostbite and renders it more severe, as it compresses the blood vessels, impairs the circulation and thus intensifies the harmful effect of the cold.

We usually distinguish three degrees of frostbite.

Exposure to moderate cold leads to frostbite of the first degree: the skin becomes numb and white. After the frozen part has been warmed, the skin becomes first red or blue, and then returns to its normal color. Slight pain quickly subsides.

Freezing caused by prolonged exposure to cold, particularly severe cold, may lead to very grave consequences: as soon as the frozen parts are warmed they become covered with blisters. This is frostbite of the second degree. Frozen parts of the skin may subsequently die off and ulcers may develop. Even muscles and bones may die off together with the skin: this is frostbite of the third degree.

Frostbite can be easily prevented. To this end it is sufficient to wear warm clothing in cold weather, including not-too-tight footwear, headgear, gloves or mittens. If no adequately warm footwear is available, it is useful to smear the feet with fat and wrap them in newspaper or some other not-too-thick paper. If one has to go out of doors in severe frost, one should smear the face and ears with fat.

If cheeks, nose or ears begin to freeze, one should rub them immediately with a clean hand. If the feet or the body feel cold, one must move about energetically to speed up the blood circulation and to warm up again. In the past it was commonly thought that frozen parts of the body should be rubbed with snow. Now, however, it has been shown that this is not advisable. The warming up should take place rapidly; rubbing with snow leads to gradual warming up. Besides, the snow frequently contains ice crystals and sand; these may scratch the frozen skin, which has a lower resistance to micro-organisms, causing suppuration.

When a victim of frostbite enters a warm room, the frozen limbs should be rubbed with vodka. They should then be immersed into a basin of water (best of all, soapy water) of room temperature, and in the water the limbs are carefully rubbed with clean hands. Gradually, /248
warmer water can be added to the basin and in this way the temperature of the water can be gradually increased over a period of 15-20 minutes

up to human body temperature (about 37°C). Rubbing of the limbs in the water must be continued until the skin takes on a red color. If there is no possibility of carrying out this massage in water, the frozen parts must be carefully rubbed with a clean dry towel or dry hands.

After the frozen parts have become red, they should be smeared with fat, oil, cod liver oil or boric acid ointment and warmly wrapped. The frozen parts must be kept covered with fat and wrapped in a warm material for several days even when they appear to be completely healthy. This is particularly important if one has to go out of doors into the cold.

When blisters or ulcerations appear, they must be covered with sterile dressings, just as in the case of a wound or a burn, and the doctor must be consulted immediately. Another reason for immediate consultation with a doctor is the urgent necessity for a protective inoculation against tetanus.

First Aid for Victims of Exposure to Cold

If the victim of exposure is unconscious, he must be immediately moved into a room of normal temperature. Here he must be washed with warm water, if possible rubbed with cotton wool, and then the body must be rubbed with clean hands until the skin becomes red again and movement is restored into the limbs. At the same time, the victim of exposure must be warmed. For this purpose he must be laid on warm blankets and covered with warm blankets and hot water bottles.

If the body of the victim has warmed but consciousness fails to return, he should be given smelling salts. He should not be given anything to drink before he regains consciousness as he might aspirate the liquid. When consciousness has returned, the victim can be given hot tea or spirits and kept warmly covered in bed.

If the victim of exposure does not breathe or is barely breathing, artificial respiration must be started at once. Selection of the type of artificial respiration employed will depend on which parts of the body have already been warmed up and are sufficiently mobile (to avoid bone fractures).

Burns and First Aid in Cases of Burns /249

Injuries to the human body caused by the action of high temperature, i.e., by excessive heating, are called burns. Burns may be produced by flames, hot liquids, steam, hot air and so on.

In combat conditions, burns may be caused by inflammable mixtures and by atomic weapons of explosive effect. Incendiary substances such as napalm, phosphorus and others, cause burns by their flames. In the case of atomic explosions, burns are caused by the light flash as well as by heated air. In addition, burns may occur when fires break out in populated places, defense works, in aircraft, when fuel on airports catches fire and explodes, and so on. In all these cases burns are caused by flames.

Uncovered parts of the body suffer most of all from burns, as clothing protects the skin to a considerable extent against burns caused by flames, hot air, and particularly light flashes. For this reason, burns of the face and hands are the most common combat injuries.

However, if clothing, particularly when it consists of several layers, catches fire, the injury is usually extensive and severe. The longer the time of exposure to excessive heat, the more severe the burn. In the case of atomic explosions, the burns caused by the light flash and the heated air occur in a single moment. Incendiary substances sticking to the skin, however, or clothing which has caught fire, may burn for a prolonged period and the longer they burn the more severe the injury. For this reason our first-aid efforts must first of all be directed towards the extinction of the flame, or removal of the burning substance or burning clothing. This is the first step in first aid for the victims of burns.

A fire extinguisher which emits a jet of water mixed with carbon dioxide in the form of foam has proved to be the most adequate means of extinguishing flames.

If he happens to be near a river, the victim wearing burning clothing may jump into it. If there is no water nearby, the flame can be put out by smothering with something dense. Sometimes it is easier to tear off the clothing than to put out the fire. In winter, burning clothing can be most easily extinguished by covering it with snow or by rolling in the snow and burrowing into it.

Napalm drops burning on the skin must be extinguished by immersing the corresponding parts of the skin in water or pouring water over them. In winter a piece of snow can be pressed against the burning drop of napalm, or the burning part of the body can be plunged into the snow. The burning napalm should not be scratched from the skin. This will /250
only cause the sticky substance (a mixture of gasoline and tar) to be smeared over the skin and burn an even larger area. In addition, napalm will stick to the hands and start to burn them as well.

If neither water nor snow is available, burning drops of napalm must be firmly covered by an overcoat or other material, preferably moistened with water. If napalm drops have fallen onto outer clothing, these should be torn off as far as possible.

The same methods can be used to extinguish burning phosphorus, but in this case the burning particles are easier to remove from the skin or clothing. Phosphorus has the property of catching fire spontaneously in contact with air. If the flames of burning phosphorus have been extinguished with water, the fire will start again as soon as the phosphorus dries up. To prevent this spontaneous combustion, the skin must be cleaned of the phosphorus before it has time to dry. Phosphorus is easy to remove.

In medical practice we discern burns of the first, second, third and fourth degree (not counting injuries caused by atomic weapons).

What then happens if any part of the human body is exposed to excessive heating?

First of all, more blood will flow to the affected part of the skin and the skin nerves will be stimulated. The skin becomes bright red and the victim feels warmth and a burning pain. If by the time the heat has subsided, the injury does not develop any further, this is called a burn of the first degree. This is the mildest type of burn. In the case of burns of the first degree, the pain lasts for a few hours and then subsides. The red color of the skin also disappears very quickly.

If parts of the body are exposed to greater heat or for a longer period, burns of the second degree can develop. On the reddened skin, blisters develop which are covered by a thin transparent layer separated from the external layer of the skin by a yellow or slightly sanguineous liquid. The pain is more severe and, more important, lasts longer - up to 2-3 days.

If the action of the high temperature is even stronger, burns of the third degree will occur. In this case the skin is cooked; proteins within the skin coagulate, as the white of a chicken egg will coagulate when boiled. The skin dies off.

Finally, in the case of burns caused by flames, the skin sometimes not only dies off but burns out, turning into carbon. At the same time, deeper tissues of the body such as muscles, bones and the /251
ligaments in the joints are frequently affected. This type of burn is called a burn of the fourth degree.

In burns of the second, third and fourth degree, the skin is broken and consequently micro-organisms causing suppuration, as well as radioactive substances, may penetrate the tissues. Where burns extend over a large area, strong pain, the resorption of breakdown products from the burned tissues, as well as the loss of great quantities of water will lead to severe disorders in the victim's general condition.

Burns of the first degree become dangerous to life if they occupy two-thirds of the body surface; burns of the second degree, if they occupy half of the body surface; and burns of the third degree, if they occupy one third of the body surface.

Burns are mainly dangerous because of the extreme pain and because of possible contamination by micro-organisms or radioactive substances. Consequently, the treatment of burns consists mainly in measures to relieve the pain and to prevent contamination by micro-organisms or radioactive substances. Combatting pain is of importance only for extensive burns, since pain from burns extending over a small section of the skin cannot impair the vital functions to a dangerous degree. On the other hand, measures against infection are of the greatest importance whatever the extent of the burn and hence should be begun as soon as possible.

If incorrect first aid is rendered to victims of burns or if they consult a doctor too late, deforming scars may remain and may sometimes incapacitate the victim for a considerable time. Another reason for early attention by a doctor lies in the fact that in many cases anti-tetanus injections should be given as soon as possible.

Where burns of the first degree are suffered, in which the skin is only reddened but unbroken, moistened dressings can be applied which not only lessen the pain but also protect the skin against infection. These dressings should be wetted with a solution of potassium permanganate, alcohol, vodka or eau-de-cologne.

In the case of burns of the second, third or fourth degree, when the skin is broken, first aid must be rendered with particular caution to prevent wound infection. A sterile dressing, i.e., one free of bacteria, is the best protection against infection. For this reason the burns should in most cases be covered with dressings taken from personal first-aid kits and should be bandaged. While doing so, /252
one should avoid at all costs damage to the blisters which may form. As long as the blister is unbroken, bacteria can hardly penetrate into it. Blisters, particularly broken blisters, and the wound surface in general, should never be touched by hand. The surface of burns of the second and third degree should never be smeared with anything.

While putting on the dressing, one should never tear off pieces of clothing which may have become attached to the burned area of skin. Such pieces have to be cut out with clean scissors boiled in water or washed in alcohol, leaving a few cm from the actual burn, and covering with dressings. In the case of extensive burns all over the body, the victim must not be undressed but must be covered with a clean freshly ironed sheet with warm blankets over the sheet in such a manner that no pressure is exerted on the site of the burn. The victim should then be given hot strong tea and be sent as quickly as possible to a medical center.

The light flash emitted by an atomic explosion may cause extensive burns through thin layers of clothing, without setting the clothing alight. In this case, the majority of micro-organisms present on the clothing will perish due to excessive heat. As a result, the danger of infection due to contact with underwear is considerably lessened. In the case of extensive burning of the limbs, they should be put in splints.

First Aid in the Case of Electrocution

Electrical current may cause local injuries or general disorders. Local injuries become manifest on the skin most frequently at the points of entrance and exit of the current in the form of whitish gray spots, scratches, bleeding, or burns of all degrees. The general effects become manifest in pallor of the skin, spastic convulsions of the muscles, loss of consciousness, respiratory disorders and weakening of the heart function.

First aid must begin with the interruption of the current. For this purpose we have, depending on the circumstances, to either switch it off or cut the cable, or pull away the wire from the victim, or separate the victim from the ground by means of a dry board, clothing, etc.

The person rendering first aid must put on rubber gloves or rubber boots, or wrap the hands in woolen or vulcanized material, and stand on a dry board, to protect himself from the action of the current. /253 As soon as the current has been interrupted, artificial respiration must be started immediately, not waiting for the arrival of a doctor, if the victim shows no signs of life. In this case every minute is precious. Artificial respiration should be continued without cease for a prolonged period, sometimes for several hours, until resuscitation occurs. This persistence is also necessary in view of the fact that victims of electrocution frequently get into a state of so-called apparent death. In this case the cardiac activity and the respiration are suppressed to such a degree that they can be established only with the greatest difficulty. If the absolute signs of death appear, such as discoloration or rigor, artificial respiration may be stopped.

At the same time as artificial respiration is being given, the victim should be warmed and given smelling salts. As soon as the first signs of life reappear, the victim must immediately be admitted to a hospital.

There exists a harmful, incorrect idea according to which the victim of electrocution (for instance a man struck by lightning) should be buried alive. It is assumed that by so doing, "electricity will leave the body" and he will revive. This is superstition. No electricity whatever remains in the body of the victim. After all, electrocution consists in the fact that current passes through the body and enters the earth. If a man is "not earthed", for instance if he wears rubber boots, and the current cannot reach the earth, there will be no injury; current will not flow through the human body even if the person grasps a high-tension cable.

To bury the victim of electrocution alive means to lose time and consequently lessen the possibility of saving a life. Besides, existing burns may be contaminated with earth, which usually contains organisms causing suppuration, and sometimes tetanus bacilli.

All victims of electrocution who have been unconscious for a time or who suffered for a long time from the after-effects of the shock must be immediately sent to hospital, even if they feel quite well.

First Aid for Victims of Heat-Stroke and Sunstroke

Heat-stroke occurs due to general over-heating of the body; it may occur even when the normal heat loss into the ambient medium is impaired. High humidity, lack of wind, high temperature or the wearing of warm, poorly ventilated clothing in hot weather will enhance the development of heat-stroke. Heat-stroke may occur not only in the open air but also in stuffy enclosed premises, cabins and so on. Sunstroke can occur only in the summer, due to prolonged exposure of the bare head to the direct action of the sun's rays. /254

Heat- and sunstroke have some common symptoms: red face, general weakness, headache, palpitations, vomiting, dyspnea, and sometimes loss of consciousness and respiratory arrest. As soon as the first symptoms appear, the victim must be immediately removed from risk of further exposure to heat or sun rays. He must be put into a cool place, preferably in the open air; his equipment must be removed; he must be undressed and ice or cold compresses placed on his head and chest. If breathing has stopped or become very weak, artificial respiration must be started. It is not advisable to apply smelling salts to the victims of heat- or sunstroke.

People working in hot weather in the open air or in hot premises should be provided with light clothing and adequate quantities of cold water, to prevent heat- or sunstroke. In hot sunny weather, prolonged exposure of the bare head to the sun is not permissible.

First Aid in the Case of Fainting

A short-lasting loss of consciousness occurring suddenly due to acute lack of blood in the brain is called fainting. Faints may occur due to fatigue, severe pain, severe loss of blood, hunger, foul air in poorly ventilated overcrowded premises. In large crowds fainting sometimes occurs, even in the street.

Initially the victim complains of dizziness, nausea, lack of air, tightness in the chest, then he loses consciousness. Weak, anemic or exhausted people faint particularly easily. The face of a person who has fainted is pale, and covered with sweat; the pulse is weak and rapid.

When rendering first aid, one must lay the victim with head down /255 and the feet raised, to increase the flow of blood to the brain. The collar and belt, which interfere with breathing, must be opened and smelling salts applied. Fainting usually lasts only a few minutes, after which consciousness returns. In these cases no cold compresses should be applied to the head.

If a person who has fainted does not breathe, artificial respiration should be applied. After the victim has regained consciousness, he should be given warm tea or coffee, be covered in blankets and warmed.

First Aid for Drowning

Water entering the lungs of a drowned person obstructs the airways and interrupts the supply of oxygen and the removal of carbon dioxide. The blood of the victim becomes poor in oxygen, and oversaturated in carbon dioxide. For this reason, the first step in rendering first aid must consist in removing water from the lungs and, in the fastest possible manner, removal of carbon dioxide from the blood, saturating the latter with oxygen.

First of all the mouth of the victim taken from the water must be cleaned of alien bodies (sand, mud, seaweed and so on). The victim should be undressed and laid with the face downwards and the chest arched over a bent knee, footstool, beam or heap of clothing, etc. The victim's head should hang down. After the victim has been placed in this position, pressure should be applied on his back. This will lead to the flowing of water from his mouth. As soon as the flow of water stops, the victim must be turned onto his back and artificial respiration must be begun. While carrying out artificial respiration, one should at the same time warm and rub the victim. In some cases resuscitation occurs only after several hours of artificial respiration.

Artificial Respiration

In cases where the breathing function of the victim is impaired to a considerable degree (after electrocution, heat-stroke or sunstroke, drowning, or cases of persons buried in earth and so on), artificial respiration must be applied.

Before it is begun, one must loosen the collar, belt and clothing of the victim, clean mouth and nose of mucus, sand or mud, /256
remove false teeth if any and pull out the tongue. If artificial respiration is carried out indoors, an influx of fresh air must be ensured by opening doors, windows or hinged small windows.

There are several methods of artificial respiration. The first method described below is the most efficient. However, this method cannot be used when the upper limbs are injured. In these cases we have to resort to the second method. Whatever the method used, 16-20 respiratory movements per minute must be carried out.

First method (Fig. 20). The victim is laid on his back and some support (made from an overcoat, clothing, etc.) is placed under the lower part of the chest. The person rendering first aid kneels near the head of the victim facing him. Then he grasps the hands of the victim and slowly lifts them, first to the side and then upwards; this causes the chest to expand and inspiration takes place. Having waited 2-3 secs, the person rendering first aid bends the arms of the victim at the elbows, brings them down to the trunk and presses them hard against the side of the chest. This causes compression of the /257
chest and expiration will take place. 16-20 of these movements have to be carried out every minute.

Second method (Fig. 21). The victim is laid on his back as in the first method and a support is placed under the lower part of the chest. The person rendering first aid kneels, taking the thighs of the victim between his knees, and places the palms of his hands on the victim's chest in such a manner that his two thumbs touch each other near the lower end of the sternum. Bending forward he presses with the whole weight of his body upon his extended hands and in this way compresses the chest of the victim which leads to expiration. Having waited 2-3 secs, the person rendering first aid straightens up and ceases to exert pressure on the chest of the victim; this leads to inspirium.

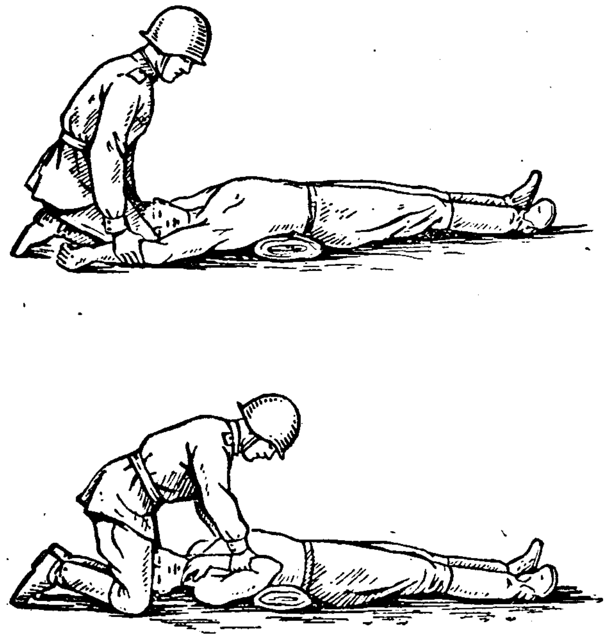

Fig. 20. Artificial respiration (first method).

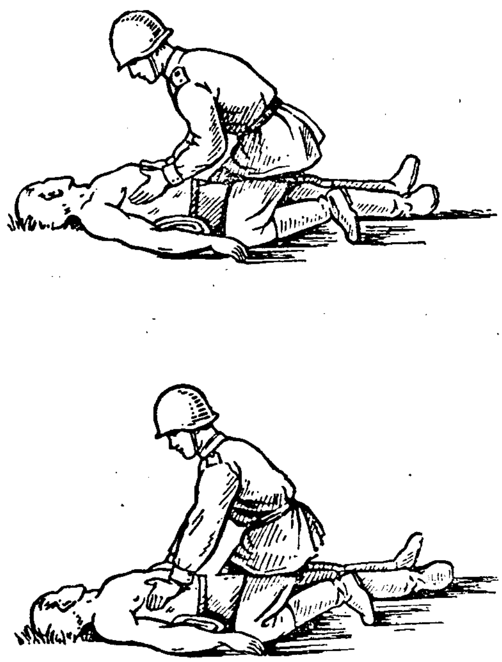

Fig. 21. Artificial respiration (second method).

The Importance of First Aid, Self Help and Mutual Aid

By first aid, we mean aid received by the victim at the site where he was wounded or suffered an accident before he is sent to a hospital. When rendering first aid the aim is to try to eliminate those factors which threaten the victim's life and prevent those complications which might arise during transport to hospital. First aid rendered in time and in a correct manner has a beneficial influence upon the further course and final outcome of the injury. For /258 instance, arrest of hemorrhage from the large blood vessels will prevent the death of the victim due to loss of blood; application of a sterile dressing will prevent wound infection by micro-organisms or contamination by radioactive substances as well as the ensuing complications. In cases of closed fractures, immobilization of the limb will prevent the closed fracture from becoming an open fracture, etc.

In the complex conditions of modern combat situations, the medical staff will not be able to render first aid in all cases of injury. A considerable proportion of the victims will be forced to resort to self help (i.e., help rendered by the victim himself) or to mutual aid (i.e., aid rendered to an injured comrade). For this reason every serviceman should be able to render first aid to himself or to an injured comrade and the commanding officer must be able to organize first aid.

First Aid in the Case of Combat Injuries

All injuries suffered by the human body are divided into closed and open injuries.

In the case of closed injuries, the continuity of the external cover (skin and mucous membranes), which defends the body against the penetration of micro-organisms and other external agents, is preserved. For this reason, wound infection and the consequent complications are less likely to arise after closed injuries than after open injuries.

By wound, we understand a disruption of the continuity of the cover combined with damage suffered by the deeper tissues and internal organs.

Due to injury to the blood vessels, every wound is accompanied by hemorrhage of greater or lesser intensity. Severe hemorrhage, like that arising after damage to large arteries, threatens the victim's life due to loss of blood. Less intensive bleeding cannot be the immediate cause of death but predisposes him to the development of severe complications: shock, suppuration of the wounds, sepsis, etc. For this reason one of the most important tasks of first aid consists in the arrest of hemorrhage.

35

Micro-orgamisms and radioactive substances may enter the wound through the disrupted skin or mucous membranes. They may cause suppuration and delay or distort the healing process. The greater the number of micro-organisms or the greater the quantity of radioactive substances contaminating the wound, the more likely are complications to arise and the more severe they will be. For this reason it is of great importance to avoid further contamination of the wound when rendering first aid, notwithstanding the fact that almost all wounds are infected anyway with micro-organisms present on the object which caused the injury. /259

Hence it follows that in the case of wounds, first aid consists first of all in the arrest of hemorrhage and prevention of wound infection. If the wound is extensive, the injured organ should be immobilized.

In combat situations all kinds of projectile-caused injuries may occur. If atomic weapons have been used, injuries caused by the direct effect of the shock-wave or debris carried away by the shock-wave will be encountered. Splinters of shells, mines, bombs as well as debris of all kinds carried away by the shock-wave, and possessing a high kinetic energy, may cause extensive damage to muscles, blood vessels, nerves and bones. Numerous bone splinters may on their part cause further injury to surrounding tissues. Damage suffered by the large blood vessels increases the danger of hemorrhage and the presence of injured non-viable tissues, the latter being an ideal nutrient medium for micro-organisms.

The Arrest of Hemorrhage

Hemorrhage accompanies every wound but in the majority of cases it stops spontaneously due to the capacity of the blood to coagulate. If, however, larger blood vessels are damaged, the bleeding will not stop on its own. In these cases, first aid measures to stop the bleeding must be taken.

Depending on the type of blood vessel damaged, we distinguish between arterial, venous and capillary bleeding.

Arterial bleeding arises due to damage to arteries and is the most dangerous of all. Here, blood flows in a strong pulsating jet and is of a bright red color. Injuries to large arteries may cause death if the victim does not receive first aid immediately. If large arteries located in the limbs are injured, it is necessary to apply a tourniquet. /260

36

Venous bleeding, which arises when veins are damaged, is characterized by the fact that the blood flows more slowly and evenly and is of a dark red color. In the majority of cases, the bleeding can be stopped by applying a pressure dressing.

Capillary bleeding arises after injury to the smallest blood vessels - the capillaries. It is characterized by the appearance of numerous blood drops on the surface of the wound. Capillary bleeding tends to stop on its own and will certainly stop when dressings are applied to the wound.

Bleeding can be arrested finally or temporarily. Final arrest of bleeding is the task of a doctor in a hospital. When rendering first aid, only temporary arrest of bleeding can be achieved. The choice of the method used to achieve temporary arrest of bleeding will depend on the character and intensity of the hemorrhage.

The following methods are used to achieve temporary arrest of bleeding: application of a pressure dressing; application of a tourniquet; pressure of the arteries against the bone along its whole length exerted by the fingers; maximal flexure of the limb and fixation in this position.

A pressure dressing is applied as follows: a cotton-wool-gauze pad from the personal first aid kit is applied to the bleeding wound and fixed tightly with a bandage. It is advisable to cover the cotton-wool-gauze pad applied to the wound with a piece of cotton-wool or a second tightly wrapped cotton-wool-gauze pad from another first aid kit before the bandage is applied. The limb to which the pressure dressing is applied should be placed as high as possible. For this purpose the arm should be put in a sling and the leg can be supported by a folded overcoat. Application of a pressure dressing will bring about in most cases the arrest of a venous hemorrhage and in some cases, when only small arteries are concerned, even of arterial hemorrhage.

Bleeding from medium size or large arteries which cannot be stopped with the aid of a pressure dressing just be stopped by the application of a tourniquet (Fig. 22). In this case the following should be kept in mind: firstly, application of a tourniquet for more than two hours /261 without interruption may lead to the dying-off of the limb; secondly, too tight an application of the tourniquet may damage nerves and cause paralysis of the limb; thirdly, a tourniquet interrupts the circulation in the peripheral part of the limb which favors the development of pyogenic micro-organisms in the wound. Hence it follows that whenever possible pressure dressings are preferred to tourniquets.

When applying a tourniquet the following rules must be observed:

1. The tourniquet must be applied above the wound but as near as possible to it.

2. The tourniquet must be applied on top of the clothing.

3. The tourniquet should not be tied too tightly. The pressure caused by the tourniquet should be sufficient to stop the bleeding (enough to cause the pulse to disappear) but not strong enough to cause nerve injuries.

4. The tourniquet should not be applied for more than two hours.

5. A wounded person to whom a tourniquet has been applied should be immediately hospitalized.

6. When an injured person wearing a tourniquet is evacuated, the day and hour of application must be shown in a clearly visible manner, i.e., by writing on the dressing, etc.

7. In cold weather the limb to which the tourniquet has been applied must be wrapped in warm clothes.

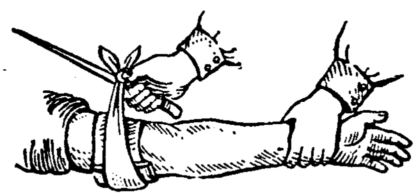

Fig. 22. The application of a tourniquet.

Special rubber or plastic tourniquets exist for the stopping of bleeding. In the case of self help or mutual aid, however, any materials at hand can usually be used (belts, handkerchiefs, a strip of clothing, etc.). A loop is made with these materials, a stick is drawn through the loop and screwed until the bleeding stops. After this, the ends of the stick are fixed to the limb with the aid of a bandage.

Temporary arrest of bleeding can be achieved by pressing the fingers against the main arterial trunks at a certain distance from the wound. This method is tiring but is of great importance as a temporary measure in case of severe hemorrhage and can be continued until other, /262 more effective, measures can be taken (e.g., a tourniquet). The bleeding of a limb can be stopped by pressing the fingers against the arteries above the wound in those places where the blood vessel runs near the bone.

Bleeding from the hand, forearm or the lower part of the upper arm can be stopped by compressing the brachial artery. The upper arm is grasped from behind in such a manner that the thumb touches the inner margin of the biceps. By exerting pressure with the thumb against the bone, the brachial artery can be compressed (Fig. 23).

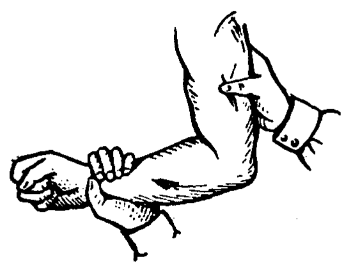

Fig. 23. Arrest of hemorrhage by compression of the brachial artery.

Bleeding from the lower limb can be stopped by compressing the femoral artery. For this purpose the upper part of the thigh is grasped with both hands near the groin in such a way that the two thumbs - put upon one another - are placed inside the middle line of the thigh and press the artery against the bone.

In some cases, bleeding from limbs can be stopped by compressing the blood vessels. This is achieved by maximal flection of the joints. In the case of foot or calf injuries, bleeding can be stopped by bending the leg in the knee joint and bringing the calf near to the thigh and fixing it in that position; before the leg is bent, a personal first aid pack, a wad of cotton-wool, a handkerchief or similar object should be placed against the back of the knee joint.

Bleeding from the hand and forearm can be stopped by bending the arm at the elbow joint and fixing the forearm against the upper arm. Bleeding should never be stopped by maximal bending of the limbs if any bones are broken.

Wounded people who have lost large quantities of blood suffer from severe symptoms caused by the inadequate blood supply to the brain. To increase the flow of blood to the brain in these cases, an injured person should be placed with the head down and the limbs raised. To replace the lost blood, an injured person should be given repeated drinks, preferably of a hot liquid. A wounded person should /263
be kept warm with hot water bottles and be wrapped in overcoats or blankets. A wounded person suffering from hemorrhage should be immediately hospitalized.

Protection of Wounds Against Micro-Organisms

After the bleeding has been stopped, the danger of wound contamination by micro-organisms must be averted. For this purpose, dressings are put on the wound. If the bleeding has been stopped by means of a pressure dressing, the same also serves as a protection against micro-organisms. By absorbing the discharge from the wound, the dressing presents a barrier to the existence and multiplication of microbes contaminating the wound, which got into it with the object that caused the injury. The dressing should be hygroscopic (absorbent) and asceptic (i.e., completely disinfected and free from micro-organisms). The dressings are sterilized by exposure to high temperatures.

The skin surrounding the wound must be uncovered before the dressing is applied. For this purpose, the appropriate part of the clothing is raised or cut with a knife or scissors, or torn off. However, the victim should not be uncovered too extensively to avoid excessive cooling of the body. If tincture of iodine is available, it can be used to paint the skin around the wound. While putting on the dressing, the wound must not be touched by hand or washed or dusted with powder and no attempt should be made to remove alien bodies.

If the dressing is applied under combat conditions, the personal first aid kits carried by every soldier are used.

The personal first aid kit consists of a gauze bandage provided with two cotton-wool pads intended for dressing the points of exit or entry of a bullet. Each pad consists of two layers of gauze with cotton-wool between them. One of the pads is firmly fixed to the end of the bandage, while the other can be freely moved along it. The outer surface of the pad is marked with a colored thread and only this surface may be touched. The inner surface of the pad is intended for direct application to the wound and should never be touched. The bandage with the two pads is sterilized, wrapped in parchment paper and stored, together with a safety pin, in a hermetically sealed pack /264 made of oiled fabric and then in a canvas pack. Such packing prevents contamination by micro-organisms during prolonged storage under any conditions. Such bandages are intended for dressing wounds.

The bandage must be tied to prevent the dressing shifting from the wound surface. It should not, however, be tied too tightly as this may compress the blood vessels and interfere with the circulation. Tight bandages are permissible only on pressure dressings used to stop bleeding.

When dressings are applied to a limb, the limb must be placed into such a position that this position need not be changed after the bandage has been applied. The bandaging should begin from the periphery, gradually proceeding to the basis of the limb. Each subsequent turn of the bandage should overlap the preceding turn by about one half. It is sometimes necessary to twist the bandage to achieve better fitting.

When applying dressings to head injuries, circular runs of the bandage should be made round the head, as well as vertical runs over the chin, so as to keep the dressing in position. In the case of face injuries, tail dressings can be applied, i.e., where the ends of the bandages are torn lengthwise. The untorn middle part of the bandage is used to press a pad upon the wound and the torn ends are crossed and tied at the back of the neck.

Application of a dressing to the chest. In the case of chest injuries it frequently happens that air passes through the wound opening at each expiration or inspiration causing severe respiratory and circulatory disorders which threaten the wounded man's life. When rendering first aid, the wound must be hermetically closed so as to prevent passage of air. For this purpose the wound surface should be covered with the torn up oil skin of the first aid kit. This is covered by the cotton-wool-gauze pad, which is kept in position by circular bandages round the chest. To prevent the dressing from /265
slipping, a strip of bandage is bound round the shoulder before the dressing is applied. Afterwards, the free ends of this strip are tied in a knot on the other shoulder (Fig. 24).

In the case of injuries to the abdomen, the intestines may prolapse from their cavity. It is not permissible to replace them into the abdominal cavity when rendering first aid. The dressing must be applied over the prolapsed organs. The dressing must be fixed by bandages applied round the abdomen and thighs. Victims of abdominal wounds must not be given food or drink.

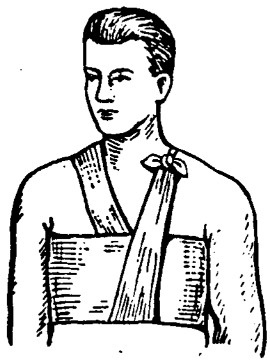

Fig. 24. Bandaging the chest.

First Aid in Case of Bone Fractures

Disruption of the continuity of the bone is called a fracture. There are closed and open fractures. In the case of closed fractures, the skin is unbroken, and, in the case of open fractures, it is broken. Fractures occur most frequently in the bones of the extremities. The following are the symptoms of bone fractures in a limb:

- impossibility of moving the injured limb;

- the shape of the limb is changed and it is shortened;

- palpation of the site of the assumed fracture is extremely painful;

- the bones can be moved at an unusual point, where no joint exists;

- a grinding noise can be heard which is made by the friction of the broken bone ends;

- in case of open fractures, bone splinters can be seen in the wound with the naked eye.

By no means will all the above enumerated symptoms be found in every bone fracture. Diagnosis of a fracture is sometimes difficult even for an experienced surgeon. This means that whenever a bone fracture is suspected, first aid should be applied in the same way as if it were a genuine fracture.

If a limb is broken, every movement causes the broken ends to shift; the sharp edge of the broken bones may damage the soft tissues. This may lead to injuries to large blood vessels and nerves. In case of closed fractures the bone splinters may break through the skin thus converting the closed fracture into an open one.

In the case of fractures, first aid must be mainly directed at preventing movement of the bone fragments. This is achieved by immobilizing the extremity.

Immobilization means to fix the limb so that it cannot be moved. /266
In the case of open fractures the immobilization must be combined with a wound dressing to protect the wound against infection.

In the case of shot wounds, immobilization of the extremities prevents the injury of soft tissues by bone splinters, eases the pain, prevents wound infection and helps to stop hemorrhage. Therefore, immobilization must be achieved not only in bone fractures but also in the case of injuries to joints or extensive lacerations of soft tissues, particularly in cases in which the injury caused profuse bleeding.

Transport immobilization is temporary immobilization for the period of evacuation to hospital.

Transport immobilization is achieved with the aid of splints. These may consist of wood, metal or other materials. The splint is fixed with bandages, scarves, belts, ropes, etc., to render the extremity completely immobile. Special wire-mesh and veneer transport splints are available. However, in the case of self help or mutual aid, any material at hand must serve as splint: boards, rifles, sticks, etc. When immobilizing a limb the following rules must be observed:

1) Before the immobilization, wound dressings must be applied;

2) the splint must be applied over the clothing;

3) soft padding consisting of cotton-wool, hay, grass etc., must be inserted between the splint and bone prominences in the region of the joints;

4) the splint must not be bandaged too tightly to avoid compression of the blood vessels and impairment of the circulation;

5) the splint should cover the two joints in the vicinity of the fracture. If, for instance, the shinbone is broken, the splint should

cover the knee joint and the ankle joint, or if the fore-arm is broken, the elbow joint and the wrist joint must be immobilized.

Fractures of a collar bone, shoulderblade or upper armbone: in these cases immobilization is achieved by putting the limb in a sling and bandaging it to the trunk, whereby the arm must be bent at the elbow joint to form a right angle. The palm of the hand should be turned towards the trunk. The armpit should be padded: for this purpose the personal first aid kit, a wad of cotton-wool or grass etc., may be used. /267

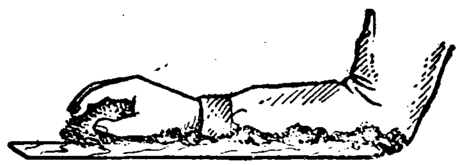

Fig. 25. Immobilization in the case of fractures of the finger or hand bones.

In the case of fractures of the fore-arm, hand bones or fingers, a board or a piece of veneer, 40-50 cm long, may serve as a splint. A pad made from a personal first aid kit, cotton-wool, grass etc., must be fixed to one end of the splint with the aid of bandages. The latter is so placed that the palm grasps the pad (Fig. 25). Then the arm is put into a sling (Fig. 26).

Fig. 26. Immobilization in the case of fractures of the fore-arm bones.

If in a case of fore-arm fracture, no material which could serve as a splint is available, the sleeve on the injured side must be fixed with a safety pin to the blouse (or overcoat) on the opposite side of the chest in such a way that the palm of the injured hand rests on the healthy shoulder; in this position the arm is fixed to the trunk with the aid of bandages. Fractures of the finger and hand bones can be immobilized with the aid of bandages wrapped round the hand; while the latter grasps a pad. In this case the fingers should be in a semi-bent position and the thumb should be in a position opposite to the second and third fingers. Then the hand is put into a sling.

Fractures of the thigh caused by shotwounds represent a severe type of injury. In such a case immobilization of the limb is essential. Three joints must be immobilized: the hip, knee and ankle joints. Adequate immobilization of the thigh can be achieved with the aid of two boards: a longer one (130-150 cm), which is placed along the trunk with its upper end in the armpit and the lower /268 and extending beyond the foot, and a short one (75-80 cm) placed on the inside of the injured limb in such a way that its upper end reaches into the perineal region and the lower end also extends beyond the foot. Both boards must be firmly fixed to the extremity (and the upper end of the longer board must also be fixed to the trunk) using bandages, belts, ropes, etc.,(Fig. 27).

Fig. 27. Immobilization in the case of thigh fractures.

The longer board may be replaced by the gun of the injured soldier (not forgetting to unload it first) with the butt towards the armpit and the barrel downwards. If no suitable material for a splint is available, the injured leg must be fixed to the healthy leg.

Shinbone fractures can be immobilized by two splints, one placed on the external and the other on the internal surface of the injured limb. The upper end of the splints should reach the middle of the thigh, the lower ends should go beyond the foot. If no suitable material such as boards, sticks etc. is available, the injured limb can be fixed to the healthy leg.

Fractures of the jaw can be immobilized by chinstraps. With their aid the lower jaw is pressed against the upper jaw and the broken ends are immobilized.

If ribs are fractured, the chest should be tightly bandaged in the position of expiration. Then the injured person can only carry out superficial respiratory movements which do not cause pain.

If the vertebral column or the pelvis is fractured the injured person must be placed onto a hard board (a door, wide board) so as to prevent injury to the spinal cord or the pelvic organs by the bone splinters. A rolled up overcoat should be placed under the knees to relax the muscles which originate from the pelvis. /269

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